With the Government Geologist's Compliments.

WESTERN AUSTRALIA

GEOLOGICAL SURVEY.

BULLETIN No. 33.

GEOLOGICAL INVESTIGATIONS

IN

THE COUNTRY LYING BETWEEN 21° 30′ AND 25° 30′ S. LAT. AND 113° 30′ AND 118° 30′ E. LONG., EMBRACING PARTS OF

THE GASCOYNE, ASHBURTON & WEST PILBARA GOLDFIELDS.

BY

A. GIBB MAITLAND
Government Geologist.

WITH PETROLOGICAL NOTES BY J. ALLAN THOMSON, B.A., B.Sc., F.G.S

Issued under the authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

WITH 13 GEOLOGICAL MAPS AND 65 FIGURES.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

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H. J. Pether, Government Lithographer, Perth, W.A.

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INTRODUCTION.

The country between the Gascoyne and Roebourne was examined by myself between the months of May and December, 1907, for the purpose of investigating and reporting upon its copper, lead, and gold resources, as well as the possibilities of the occurrence of its underground water supplies, and that of coal in the basal members of the carboniferous formation which occupies such an extensive area in the district.

The ground traversed embraces portions of the Gascoyne, Ashburton, and West Pilbara Goldfields in addition to other country outside the limits of any legally defined mineral field.

In order that the descriptive portions of the report may be more readily intelligible a series of geological and mining maps and sections have been prepared and are included.

To carry out a complete geological survey of a tract of country so extensive in the short space of time that could be devoted to the work was found to be quite impracticable and under the circumstances possibly uncalled for. The only practicable method for the production of such geological sketch maps of the country as accompany this report was to traverse sections along the route followed where the geological boundaries could be marked with such a degree of accuracy as the field maps would allow and then to join on the boundaries approximately, having due regard to the prevailing topographical features which in certain localities stand out in bold relief.

Field work was commenced at Carnarvon early in May. Leaving the township I followed the valley of the Gascoyne as far as its junction with the Lyons River. From here I travelled via the Lockier Range as far as the mining centre of Bangemall, at which locality about three weeks were devoted to such an investigation of the field as the condition of the workings allowed. Having completed the survey of Bangemall, Mounts Phillips and Augustus were visited and thence a traverse via Coorabooka made across the rough country dividing the waters of the Lyons from those of the Ashburton, as far as the Soldier's Secret mining camp.

From the Soldier's Secret, the valley of the Ashburton was traversed as far as the Dead Finish and Mount Mortimer centres, at both of which places a few days were spent. From Mount Mortimer I travelled via Coorara Claypan as far as Uaroo where there are some extensive copper and lead deposits. About four weeks were spent in this locality examining and mapping the mineral belt which proved to be about five miles in length.

From Uaroo I visited Weston's copper find which lay some miles to the west, and from thence proceeded to the Minilya River for the purpose of examining the basal members of the carboniferous strata in the vicinity of Windalia and Chugareyardoo. The hurried investigations in this neighbourhood having been completed I travelled via Yanyereddie, Glen Florrie Stations and Coorara to Mount Stuart. From this locality the Cane Hill copper workings were visited and examined, and thereafter those of Red Hill and the Fortescue River.

From the Fortescue River I travelled as far as Cossack, reaching that place early in December and Perth on the 26th of the same month, having been continuously engaged in the field for 218 days.

In order to make this report more complete there have been included a number of notes made in a hurried journey in 1900 between Cue and the Gascoyne, in connection with an investigation as to the artesian water possibilities of that country. The observations then made are of importance in connection with their bearing upon the geological features and mineral resources of the country to the north. I have also included some notes made on the tracts passed over in connection with a somewhat rapid inspection of the West Pilbara Goldfield in 1905. By the inclusion of these notes in this report a better grasp is obtained of the relation which the geological structure of the rocks of the Murchison and southern goldfields bear to those of the Pilbara Goldfields and its mineral belts.

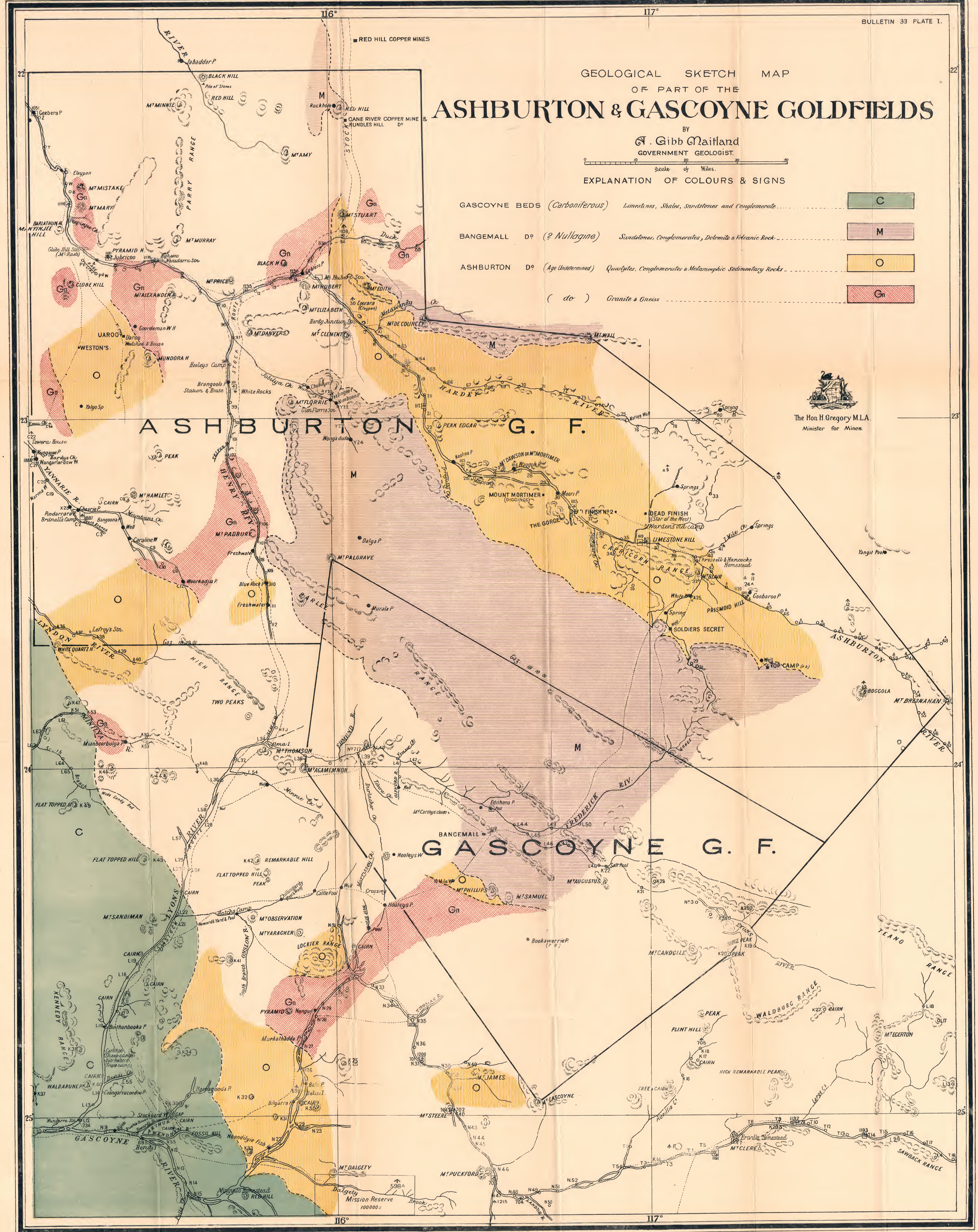
The country extending as it does over about four degrees of latitude, embraces a great many geological formations, and it will be convenient for purposes of description to deal with the areas as they were visited and having done this to give a brief summary of the mineral and allied resources of the district.

THE GASCOYNE RIVER VALLEY.

(Geological Sketch Map, Plate I.)

The Carboniferous Rocks.—The valley of the Gascoyne River from its mouth to a point a few miles below its junction with Dalgety Brook is occupied by strata of Palaeozoic, Mesozoic, Tertiary and Post Tertiary age. These strata were pierced in the bore at Pelican Hill, near Carnarvon, which had been carried down to a depth of 3,011 feet. The record of this bore shows in descending order:—About 150 feet of newer or post tertiary strata; about 1,211 feet of mesozoic (and probably cretaceous) rocks; and 1,650


M
RIVER
56
57



H.J. Pether, Government Lithographer, Perth, W.A.

feet of carboniferous beds*; the base of the latter formation, however, was not reached. This bore is of importance in that it was the pioneer bore put down in the district in the search for artesian water, and being successful led to the vigorous development of the rich pastoral lands lying between the Gascoyne and Winning Pool. It is also of importance owing to the fact that the bore yields an overflowing supply of artesian water at the rate of 520,000 gallons per day, drawn from a bed of sandstone, 448 feet in thickness, which forms the lowest bed of the carboniferous series penetrated.

The basal beds of the carboniferous series were carefully examined in the valley of the river between the Shipka and Kyber Pass and Trig. Station K. 33, near Noondilyie Fish Pool, close to where Dalgety Brook falls into the Gascoyne River. A fairly complete section of the strata lying below the fossiliferous sandy beds of the Kennedy Range has now been obtained. These Kennedy River beds contain *Spirifera, Athyris* (?), *Productus,* and *Strophalosia.*†

The beds of the Kennedy Range make a bold outcrop of about 200 miles in length and a very pronounced feature in the landscape, extending practically from the Carandibby to the Moogooloo Range. The beds cross the Gascoyne River in the vicinity of the Shipka Pass. A visit was paid to the highest point of the range near my camp at Mungarra, a few miles above the junction of the Lyons; the summit rose to a height of about 360 feet above the flats at the base. The range from base to summit consisted of fine-grained sandstones which are practically horizontal or with so low a dip as to be hardly perceptible in a single section. Portions of the beds are exceptionally ironstained and contain ferruginous concretions of all shapes and sizes. One ferruginous band is crowded with fragments of *Spirifera* and *Productus*; the fossils on the weathered surface are, like those I obtained from Trig. Station K. 37, in 1900, covered with an ironstone glaze. The few sections visible between the camp at Mungarra near L. 13, and the foot of the Kennedy Range, showed that the underlying beds consisted of sandstones of the type which characterises those of the lower portions of the Kennedy escarpment. In the bed of the Gascoyne River below Gnardune Pool these sandstones are associated with sandy shales; whilst lower down the river about two miles below Jiggerie Station a cliff on the northern bank of a large pool exposes a good section of the flaggy sandstones and sandy shales. Some miles below this and in the bed of the river where it is crossed by the main road at

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* Annual Progress Report of the Geological Survey for the Year 1902. Perth: By Authority, 1903, pp. 23-24; and Progress Report of the Geological Survey for the Year 1903 Perth: By Authority, 1904, p. 34; also possibility of the occurrence of Artesian Water in the Northampton and Geraldine Districts. Geol. Surv. Bulletin No. 26. Perth: By Authority, 1907, p. 8.

† Recent Advances in the Knowledge of the Geology of Western Australia. A. Gibb-Maitland, Geol. Surv. Bulletin No. 26. Perth: By Authority, 1907, p. 54. Also—Report of the Eleventh Meeting of the Australasian Association for the Advancement of Science. Adelaide, 1907. pp. 131-157.

Weenamia is a bed of quasi-vitreous sandstone and conglomerate with a low dip to the westward.

From our camp at Mungarra I elected to travel in a north-easterly direction by a new route with the object of going over new ground unvisited by myself seven years previously and to this end the valley of Davis's Creek was selected as being the one which seemed to afford the chance of the best sections. Camp was pitched near Stock Route Well No. 26*, on the western flanks of that range of flat-topped hills across which the Wyndham and the Arthur Rivers flow through two low gaps.

From camp at a station well and windmill, known as the Upper Davis Well, I walked to a conspicuous hill about eight miles to the north. This hill which geographically forms part of what may for convenience of description be called the Arthur Range consists of grit and fine conglomerate underlaid by a white siliceous sandstone and resting upon fossiliferous limestone, the whole dipping generally to the westward at angles varying from five to eight degrees. The limestone forms a conspicuous though low ridge which has an average bearing of 348 degrees and can be followed by the eye across country for a great many miles. This limestone rises from beneath the Kennedy Range sandy beds and is about eight to nine miles to the east of the foot of the great escarpment. In some parts of the Arthur Range the grits, etc., which directly overlie the limestone and which form the summit of many of the table hills, in which the district abounds, are very ferruginous.

Passing through the gorge of the Upper Davis in the direction of the tableland upon which Trig. Station K. 34 is situated, a line of very low-rugged hills is passed which expose the crystalline rocks beneath the carboniferous beds. These crystalline rocks consist of almost vertical beds of quartz schist, micaceous schist, and intrusive (?) porphyry. The carboniferous rocks on the northern face of the tableland dip at a very high angle to the south but this is merely local. The tableland itself is in reality a synclinal trough, the uppermost beds of which are formed of sandstone and quartzite resting upon fossiliferous limestone on the same horizon as that of the Arthur Range. The junction of the sedimentary beds and the crystalline rocks on the western face of the tableland seems to be marked by a fault trending generally north-east and south-west, which has the effect of throwing the limestones against the older strata, and not exposing the base of the carboniferous series.

In the gap formed in the range by the Arthur River to the south of Trig. Station K. 35, the cliffs give excellent sections of the strata. The beds consist of highly fossiliferous flaggy and somewhat sandy limestones, dipping to the south-west at angles of between three and five degrees. About a mile both north and south of this the limestones are overlaid by varying thicknesses of grits and sandstones of what may be called the Kennedy Range type.

The bed upon which Trig. Station K. 35 has been erected is a sandstone containing numerous ironstone nodules, etc.

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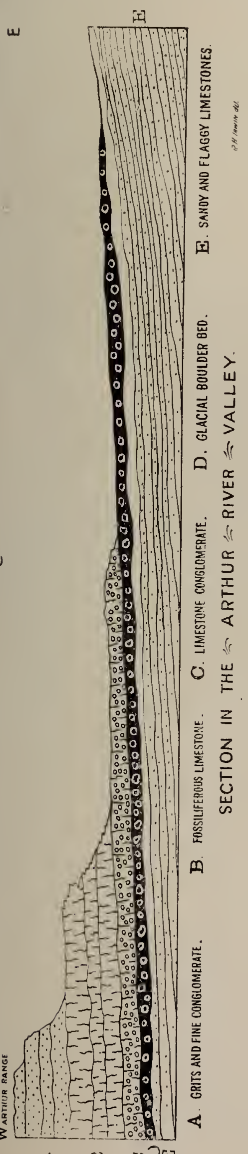
* Lands Department Lithograph No. 73.

The limestone, which forms the high bold cliffs on the northern front of the Arthur Range at K. 35 continues without interruption southwards to the neighbourhood of Minginoo Homestead (Loc. 6) on the Gascoyne River.*

Fig. 1.



A fine section of the limestone is shown where the Arthur River is breached by the Wyndham River, near Traverse Station N. 56.

Sandy limestones are also exposed in Dairee Creek in the neighbourhood of Stock Route Well No. 21, at Dairee Pool (Reserve 898); whilst fossiliferous limestone was passed through in sinking a station well at the head of the creek near Traverse Station V. 47. It thus seems that the limestone series has a fairly wide distribution in the district.

The sections exposed in the Arthur River above the range gives a fairly complete series of the basal members of the carboniferous beds, and are in addition of considerable scientific importance. A good deal of detailed work yet remains to be done in this portion of the district but a fair grasp has now been obtained of its salient geological features.

Between the Arthur Gap and Barragooda Pool, there are one or two exposures of a boulder bed of glacial origin. This bed which forms a valuable stratigraphical horizon has been followed across country for a very considerable distance.

Mr. H. P. Woodward writing in 1890† notes the occurrence of a boulder conglomerate at the base of the carboniferous series in the following words:—

"Underlying these (fossiliferous crystalline limestones, A.G.M.) are shaley beds full of very perfect fossils of Lower Carboniferous age, some of which have been even described as Devonian; the conglomerate bed containing boulders of crystalline rocks are always found at the bottom of this series resting upon clay-slate or shales which are of great thickness."

† Description of the route traversed from Geraldton to the Nullagine. Annual General Report for the year 1890. Perth: By Authority: 1891, p. 30.

From this it is evident that the beds above described can hardly be the glacial boulder bed which from the data given later indicate does not lie quite at the base of the carboniferous series.

Figure 1 gives a section of the strata in the valley of the Arthur River showing the relation of the boulder bed to the overlying limestone.

A section, Fig. 2, on the southern bank of the Arthur River shows large striated boulders embedded in a very calcareous clayey matrix. The bed as may be seen in the photograph is not very

Fig. 2.

SECTION OF THE BOULDER BED IN THE SOUTHERN BANK OF THE ARTHUR RIVER.

thick, but by weathering *in situ* its debris occupy a width in places of about a mile. It is very seldom that the boulder bed is actually seen in place, though its presence is always indicated by the heterogeneous collection of boulders, resulting from its weathering. Some of the pebbles are beautifully striated; a photograph of a scratched quartzite pebble [7545] is given in Fig. 3.

The thick bed of limestone above the boulder bed in the Arthur River shown in Fig. 1 has yielded the following fossils:—*Evactinopora crucialis,* Hudleston; *Rhombopora tenuis,* Hinde; *Athyris Macleayana,* Eth. fil. var.; *Productus semireticulatus,* Martin; *Aulosteges,* sp. nov.; *Dielasma,* sp. ind.

Fig. 3.—ICE SCRATCHED BOULDER, ARTHUR RIVER.

At a point on the Wyndham River* just to the north of the range through which it has cut a channel is another section showing the Boulder Bed, a photograph of which is shown in Fig. 4. The

Fig. 4.—SECTION OF THE BOULDER BED IN THE WYNDHAM RIVER.

* Lands Department 300 chain Lithograph 73.

bed does not attain any greater thickness than three feet, and is crowded with boulders and pebbles of granite and other crystalline rocks embedded in a calcareous fossiliferous matrix, a photograph of a specimen of which contains fragments of *Spirifera*, *Productus*, and *Polyzoa*, in addition to *Aviculopecten tenuicollis*, forms Fig. 5.

Fig. 5.

FOSSILIFEROUS GLACIAL CONGLOMERATE, WYNDHAM RIVER.

The pebbles and boulders have a large proportion of smooth and polished faces. The flats in the neighbourhood are covered with boulders and blocks of crystalline rocks, evidently derived from the weathering *in situ* of a bed of conglomerate, which has a dip of about three degrees to the south-west.

In the bed of the Wyndham River beds of flaggy sandy limestone are to be observed passing beneath the boulder bed. Associated with the boulder bed of the Wyndham River are the following fossils:—*Hexagonella dendroidea*, Hudleston, sp.; *Pleurophyllum*

Australe, Hinde; fragments of *Crinoid* stems and *Polyzoa*; *Spirifera musakheylensis*, Davidson; *Spirifera Hardmani*, Foord; *Spirifera lata*, McCoy; *Reticularia lineata*, Martin, sp.; *Athyris Macleayana*, Eth. fil.; *Chonetes Pratti*, Davidson; *Productus* (cf. *P. tenuistriatus*), Foord.

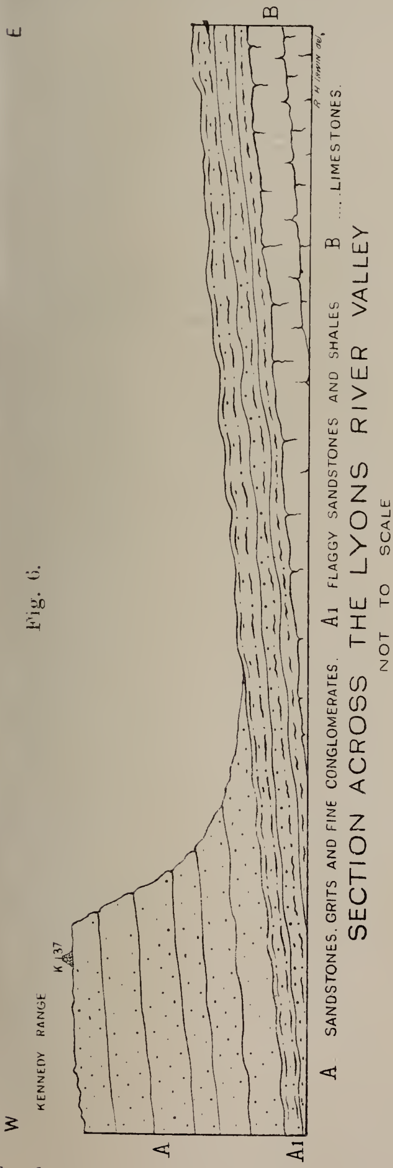


Fig. 6.

Northwards from the Wyndham River the debris of the boulder bed makes its appearance in great force; whilst the flaggy sandstones immediately underlying it are covered with large boulders of crystalline rocks.

The base of the whole carboniferous series is seen in a low isolated hill, about three miles to the west of Trig. Station K. 32. At this point a medium grained quartz conglomerate is seen to rest upon the upturned edges of the older crystalline schists. Sections in the neighbourhood show that the basal conglomerate rests upon an uneven surface.

The Wyndham River cuts through the range near Traverse Station N. 56, by a gap which exposes a fine section of the fossiliferous limestone, which in this instance dips at a low angle down stream.

Below the junction of the Wyndham and the Arthur with the Gascoyne, a few sections show the beds to consist of flaggy sandstone, sandy shales and limestones dipping westward at low angles, which pass beneath the beds forming the Kennedy Range.

The Kennedy Range forms a very conspicuous and most important feature in the landscape, and its bold escarpment is visible for many miles.

A complete section from base to summit is to be seen in that portion of the range upon which Trig. Station K. 37 is situated. By aneroid measurement the cairn is 360 feet above the base. From base to summit the section consists solely of sandstone, grits, and fine conglomerates; some beds of which are exceptionally ferruginous, and contain many ferruginous concretions of all shapes and sizes. One of these ferruginous beds is fossiliferous and contains *Spirifera*, *Athyris* (?), *Productus*, and *Strophalosia*. The sandy beds exposed in the Kennedy Range (Fig. 6) are on a slightly higher geological horizon than those on the Arthur Range.

The carboniferous rocks of the Gascoyne valley have been pierced in the experimental bore put down at Pelican Hill, near Carnarvon.

The total depth of the bore is 3,011 feet. The first 150 feet comprise rocks of either newer or post tertiary age; middle tertiary rocks (the age of which is based on the evidence of specimens of bryozoan limestones) were passed through to a depth of 1,238 feet; mesozoic and possibly cretaceous strata, down to 1,361 feet, whilst the balance of the beds are carboniferous as determined by the fossils. The carboniferous strata are represented by calcareous shales and limestone; the cores of which have yielded *Spirifera*, *Aviculopecten*, *Anthrocoptera* and *Favosites*. Full details of the various beds pierced in this bore having been given in detail in the Annual Progress Report of the Geological Survey for the year 1902, p. 24, and the Annual Report for 1903, p. 34, need not be repeated.

In the valley of the Lyons River, which in the lower portion of its course runs along the foot of the Kennedy Range escarpment, there are a few sections which showed the nature of the underlying rocks. Almost due east of Biuthanbooka Pool,* and the DeGrey-Mingenew stock route well No. 27 is a fairly conspicuous hill, made up of grit and fine conglomerate, underlaid by a white siliceous sandstone, resting upon fossiliferous limestone of the type exposed further to the south in the Arthur Range. The whole of these beds dip to the westward at angles of from five to eight degrees. This belt of limestone forms a very marked though low ridge lying about eight or nine miles east of the Kennedy Range, and having an average bearing of 348 degrees; the limestone ridge can be followed by the eye across country for very many miles.

To the south of our camp near No. 26 Well on the stock route, and on the watershed of Davis Creek, lay the high range which forms the northern extension of that through which the Arthur and the Wyndham Rivers flow, in which a fairly complete section of the strata is to be seen. The summit of the range is formed of grits

* Lands Department 300 chain Lithograph 37.

and fine conglomerates, some of the former of which are exceptionally ferruginous.

Below the sandy beds lies a mass of fossiliferous limestone, resting upon a limestone-conglomerate of the Arthur River type; beneath this conglomerate lies the boulder bed, the debris of which contains many ice-scratched pebbles and boulders.

At the headwaters of Davis Creek is a fairly lofty tableland made up of beds disposed in the form of a synclinal trough. The northern face of this tableland presents a most imposing aspect, formed by a lofty precipice in which excellent sections of the rocks are exposed. The strata on the northern face of the tableland dip at a fairly high angle, though this however is very local. A portion of the north-western end of the tableland appears to be marked by a north and south fault, which brings up the old crystalline rocks, consisting of quartz and micaschist, with dykes (?) of porphyry. These older crystalline rocks are virtually vertical and have a general strike of north-west and south-east. On the low ground between the tableland upon which the Trig. Station K. 34 rests, and the Arthur Range, the glacial boulder bed and its debris occurs in great force. It was found impossible, owing to reasons beyond control, to secure any good photographs of the bed, or the characteristic surface which its weathered outcrop formed.

The glacial conglomerate and its debris also occurs in great force some distance to the north of this, in the valley of the Lyons River just to the west of Mount Sandiman.*

THE VALLEY OF THE MINILYA RIVER.

(Geological Sketch Map, Plate I.)

A fairly complete section of the carboniferous rocks is exposed in the valley of the Minilya River.†

The upper reaches of the river however drain country made up of those crystalline schists and other rocks referred to in the later pages of this report and need not be alluded to in this place.

The head of the river is formed by two main branches; the most southerly of the two taking its rise in the high country in which the two Trig. Stations K. 44 and K. 49 are situated.

The junction between the two formations is to be seen in the south branch of the river in the "Wide Sandy Bed" indicated on lithograph 78. The older rocks in this locality consist of crystalline schists traversed by very many large and well-defined quartz reefs. There seems some reason for believing the junction between the carboniferous rocks and the older rocks to be marked by a fault.

Some distance to the westward of the junction is a very pronounced ridge of limestone, trending generally north and south and dipping to the westward. Overlying this are shaley beds.

* Lands Department 300 chain Lithograph 78.
† Lands Department 300 chain Lithographs Nos. 77 and 78.

Lower down the south branch and in the vicinity of Traverse Stations 64 and 65, the glacial conglomerate appears in very great force. The debris of the conglomerate which strews the surface

Fig. 7.

ICE SCRATCHED BOULDER, MINILYA RIVER.

consists of a heterogeneous collection of all varieties of crystalline rocks, some of which are markedly glaciated. A photograph of one

of these is given in Fig. 7. In the neighbourhood of Williambery Pool on the northern branch of the Minilya River are several sections which show the general relationship of the different beds. Close to the pool is a series of beds of limestone crossing the river and forming conspicuous hills on either bank, these rocks are to a limited extent fossiliferous, and have yielded the following:—

Amplexus pustulosus, Hudleston [4737].

Pleurophyllum Australe, Hinde [4736].

Crinoid stems [4738, 4739].

Productus semireticulatus, Martin [4740].

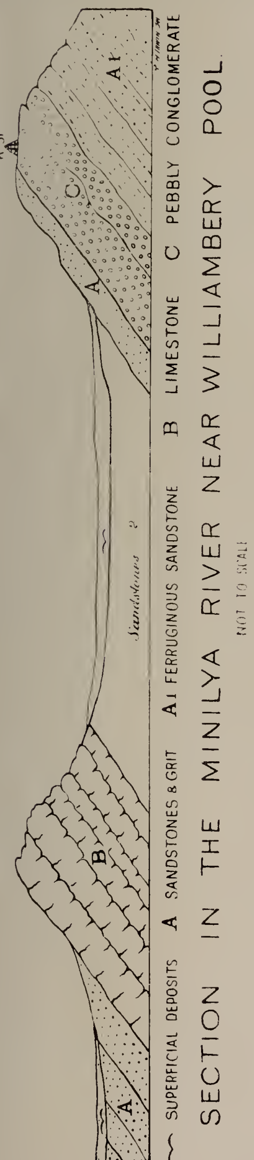


Fig. 8.

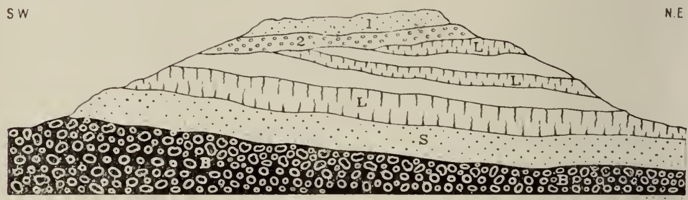
The limestone beds form a very conspicuous ridge trending generally north and south; in this section the beds dip west at angles varying from 30 to 40 degrees. The limestone is covered by sandstones; no estimate could however be made of the thickness of the calcareous strata. As seen in the hill upon which Trig. Station K. 51 rests, these limestones are underlaid by sandstones and pebbly conglomerate as shown in the section which forms Fig. 8.

Lower down the river near Traverse Station L. 66 are fossiliferous limestones dipping at low angles to the west. The limestone has yielded [4741-2] *Cleiothyris Macleayana,* Eth. fil. These limestones possibly represent the south-eastern extension of those occurring in the range due north of Moogooloo* in the watershed of the Lyndon.

On the eastern bank of the Minilya River are sections showing a distinct unconformity between the carboniferous rocks and a newer series of sedimentary rocks. About a mile to the south-west of this is another tableland, showing more marked evidence of the unconformity (Fig. 9). Beds

*Lands Department 300 chain Lithograph 94.

of fossiliferous limestone form the staple rock of the hill, and are covered by fine conglomerate and quasi-vitreous sandstone, as shown in the following section.



1 QUASI-VITREOUS SANDSTONE 2 FINE CONGLOMERATE
L FOSSILIFEROUS LIMESTONE S SANDSTONE B GLACIAL BOULDER BED
SECTION SOUTH OF TRAVERSE STATION L 66 MINILYA RIVER

Fig. 9.

Opportunity was taken to make traverses on foot for many miles to the south and numerous other sections showing the unconformity was met with and the carboniferous beds were everywhere found to dip at low angles to the south-west.

There is no direct evidence available as to the age of the beds overlying the carboniferous rocks.

No sections of the underlying strata were to be seen down the river from this point *en route* to Middalya Station, but in the river below the station some low cliffs expose a section of dark sandy shale, overlaid by conglomerate. The water from wells sunk in this shale has invariably proved to be salt. So far as may be seen from a distance, the beds forming the range upon which Trig. Station K. 55 has been erected appear to dip to the south-west.

Further down the river in the vicinity of Wandagee Station the cliffs expose clear cut sections of the rocks. They consist of dark shaley micaceous sandstone, with ironstone concretions, in the form of layers, nodules, balls, etc. Overlying these dark shaley beds, locally known as "Black Jack" are beds of buff-coloured fossiliferous micaceous sandstone. These beds have yielded:—

Chondrites [4746].

Ptychomphalina Maitlandi, Eth. fil [4747].

Chonetes Pratti (?) Dav. [4748].

Aviculopecten tenuicollis, Dana [4749-50].

Below cairn K. 59 (L. 59 of the maps) the shales and overlying beds are traversed by a series of vertical joints, which trend north-north-east and south-south-west. Many of the sandstones are coated along the bedding planes with gypsum. At the Trig. Station K. 59 the surface of the ground is covered with pebbles of quartz, etc., forming a natural macadam. It is possible that these may be due to the disintegration of a conglomerate *in situ*. Below the head station the banks of the river expose beds of dark sandy micaceous shale which are practically horizontal or with but a slight dip up-

stream. Some of the shaley beds are coated with films of gypsum which in some places reach a thickness of about two inches.

Down the river for some distance, dark sandy micaceous shales are exposed at intervals in the form of synclinal troughs, modified by faulting. These shaley beds occupy the country for about four miles below the station, when they give place to flaggy sandstones, which latter dip on the whole to the eastward. At Coolkilya Pool these beds dip at angles of from 10 to 15 degrees to the east. These beds have yielded:—*Strophalosia*, sp. ind. [**4743-4**].

Wandagee Hill lies some distance to the south of Coolkilya Pool, and rises to an altitude of about 150 feet above the general level of the surrounding plains. The hill is composed of ferruginous flaggy sandstone and grit containing a large number of what appear to be worm tracks. The northern face of Wandagee Hill presents a conspicuous escarpment overlooking the plains, and exposes a fairly complete section of the sandstones and associated rocks. Near the foot of the escarpment is a thin band of calcareous and ferruginous sandstone crowded with fossils, which were however too fragmentary for determination. A specimen however of *Chonetes Pratti* (?) Dav. [**4751-2**] was collected.

The only section of the strata exposed on the plains was in the vicinity of Mungadan Tank, on the south side of Wandagee Hill, where a calcareous flaggy sandstone was found dipping at a low angle to the east. This sandstone bears a very striking resemblance to the calcareous series as exposed in the valley of the Gascoyne River, whilst the beds of Wandagee Hill are lithologically identical with those in the Kennedy Range.

A short visit was paid to what are known as the Barrabiddy Hills, which lies some considerable distance to the south of Wandagee Hill. A well about half way between the two, and 60 feet deep passed through sandy micaceous shale with gypsum of the type exposed in the banks of the Minilya River, west of Wandagee Station. Between this well and Trig. Station K. 56 sandstone of the prevailing type is exposed and is covered by a natural macadam of flint. The low tableland upon which the cairn has been erected is composed of a white sandstone with siliceous portions and a decided "secondary" aspect. There is at present no distinct evidence of the age of this sandstone.

Almost due north of Wandagee Station is what is known as Qualing Tank, situated near the northern boundary of Pastoral Lease 67/1024, and due west of Moogooloo Hill. So far as may be judged from the debris lying round the tank, it appears to have been excavated out of beds of grey sandy micaceous shale. The low range of hills upon which K. 57 is situated is made up of beds of flaggy sandstone arranged in a synclinal fold. The sandstones contain fragments of fossil wood. The summit of the hill is covered with blown sand of a red colour. There are several meridional sandhills in the vicinity more especially in the direction of Moogooloo Peak.

THE HEAD WATERS OF THE LYNDON RIVER VALLEY.

While engaged in the vicinity of Weston's opportunity was taken to visit the upper portions of the Lyndon River for the purpose of investigating the basal members of the carboniferous rocks, to which reference had been made by my colleague in his report on the artesian water possibilities of the district.*

Some reference has already been made on an earlier page to the strata lying more immediately upon the crystalline schists, hence any description needs no repetition.

Westward from the boulder bed is a well marked limestone ridge, which contains carboniferous fossils; this belt of limestone occupies a considerable area of country in a north-west and south-east direction, the beds dip to the south-westward.

Overlying these beds are a series of sandstones and shales, which form the range upon which Moogooloo Peak stands. These beds dip at an angle of about 25 degrees to the westward; and are coterminous with those already described as occurring near Middalya Station on the Minilya River.

The beds of the Lyndon valley have been pierced to a depth of 2,359 feet in the Government bore at a spot between Maud's Landing and Winning Pool about 13 miles from the jetty. The following is a record of the strata pierced in the bore hole from data furnished by Messrs. Davis, Hankinson, & Co., contractors:—

Nature of Strata.	Thickness.	Depth.	Remarks.
	feet.	feet.	
Sandy clay and limestone ...	12	0	*At 2,275 an overflowing supply of water was met with, and the yield was 95,000 gallons per diem. The flow increased to 654,000 gallons per diem at 2,359 feet.
Clay and limestone boulders ...	23	12	
Red sandstone	15	35	
Limestone and clay	9	50	
Red clay	54	59	
Clay and limestone	123	113	
Limestone	41	236	
Limestone and yellow clay ...	44	277	
Limestone	3	321	
Yellow clay	101	324	
Blue shale	835	425	
Black shale (sticky)	1,015	1,260	
Hard sandrock	75	*2,275	
Grey shale	9	2,350	
	2,359	2,359	

No opportunity has been available for examining the core samples, hence it is impossible to state whether the whole or any of the beds pierced belong to the carboniferous series or are of younger age. It is however more than likely that the limestones and shales

* On the Country between the Ashburton and Minilya Rivers, with a view to determining the Northward extension of the Gascoyne Artesian Area, by H. P. Woodward. Geol. Sur. Bulletin 26. Perth: By Authority, 1907, pp. 10–13.

outcropping on the range of hills to the west of Cardabia Creek and upon which the Trig. Station A. 8 stands represent some of those met with in the bore hole.

THE PRECARBONIFEROUS METAMORPHIC ROCKS BETWEEN THE WOORAMEL AND THE ARTHUR RIVERS.

(Geological Sketch Map, Plate I.)

The older rocks which lie to the east of the carboniferous strata have been more or less carefully examined in the country between Coor-de-Wandy, on the headwaters of the Wooramel and Trig. Station K. 32, near the head of the Arthur River.

From the Murchison River where it is crossed by the main road near Milly Milly Station the country, as far as Innouendy on the Wooramel River, is underlaid by granite and granitic gneiss or foliated granite. The general strike of the foliation is north-east and south-west whilst the planes are practically vertical. Granitic rocks are seen in the Wooramel River a little above Innouendy. From the latter locality, a traverse several miles due north exposed no section other than residual sands until the mountain, shown on the maps as Coor-de-Wandy, is reached. This hill upon which a Trigonometrical Survey Station has been erected is composed of beds of quartzite and conglomerate, intersected by numerous quartz veins.

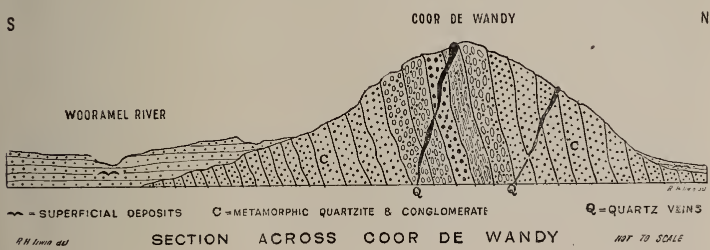


Fig. 10.

The beds which have a general north-east and south-westerly strike and a high northerly dip are traversed by numerous joints which cut clean through many of the pebbles in the conglomerate as though a saw had been used. Some little distance to the north-east of Coor-de-Wandy is another very conspicuous hill, Yalbra, the summit of which is by aneroid 200 feet above its neighbour. The beds exposed consist of highly inclined quartzites of the usual type striking generally east and west.

No section was to be seen showing the relation which these metamorphosed sedimentary rocks bore to the granites lying to the southward. Yalbra is continued to the north-east by a series of

long low ranges upon which Trig. Station VI. has been built. and are probably of the same geological constitution.

Further northwards between Dalgety Brook and Jerinoo Creek is a range locally styled the Baradalco Hills which lie due south of Location 67 237. These hills are composed of quartz and micaschist intersected by pegmatitic veins.

The Baradalco Hills owe their prominence to a series of much harder bands of crystalline rocks which stand up in bold relief. The most prominent ridge which constitutes the backbone of the range is a vertical bed of white quartzschist forming a band of about 40 feet in width. The quartzschist breaks up into very thin slabs which strew the surface for a considerable distance. Some of the quartzites contain large quantities of oxide of iron. One prominent band forming high precipitous cliffs trends generally east-north-east and is vertical. This particular band does not contain any very high percentage of oxide of iron.

The beds of quartz schist can be traced by the eye across country for a considerable distance. The western flank of the hills is formed by a low comparatively bare ridge of granitic gneiss intersected by thin greenstone dykes. Just to the north of the Baradalco Hills and on one of the tributaries of Dalgety Brook is a very large and conspicuous quartz reef forming the summit of a ridge the average strike of which is east-north-east and west-south-west. Very many similar veins may be seen when the country in the neighbourhood is viewed from any commanding eminence.

The Bundalyia Range is a long ridge of hills trending generally north-east upon which are several very prominent summits lying between the Baradalco Hills and Mount Puckford. The beds of which the range is made up consist of quartzite and micaschist, many of the harder bands of which stand out in bold relief.

Some little distance up the creek a foliated granite [2286] is seen; the fine foliation of the granite has a general strike of west-north-west and with a steep dip to the west. The relation of the foliated granite to the metamorphic sedimentary series is not clear owing to there being no continuous sections visible anywhere in the area under observation.

Many of the branch tributaries of Dalgety Brook in the vicinity of the granite are flanked with a few feet of a granitic sand ("arkose") which owes its origin to the disintegration and subsequent consolidation of the underlying rocks.

Westward of the sections previously described are others in the vicinity of Jalyie Hill the position of which is determined by the following bearings:—Mt. Dalgety, 350deg.; Yalbra, 153deg.; and Coordewandy, 158deg. A fairly large development of vertical strata of micaschist and quartzite, intersected by quartz and ironstone veins occurs. The beds strike generally north-west and south-east and form the fairly level country to the north of the boundary of the base of the carboniferous series. Associated with the schists

is a vertical bed of somewhat siliceous limestone [2283] about 300 feet in width; it however is not very extensive.

Similar metamorphic sedimentary rocks occupy a large extent of country for they are continuous as far as Trig. Station K. 33, which has been erected upon the highest summit of a prominent though low hill west of Noondilyie Fish Pool on the Gascoyne River. The hill is made up of a vertical quartzite (?) trending north-east and south-west associated with micaceons schist. From K. 33 the boundary of the carboniferous rocks can be seen forming a rampart trending generally northwards. These pre-carboniferous sedimentary beds continue as far as Wongalburra, a few miles farther up the river.

The country drained by the headwaters of the Arthur River near Trig. Station K. 32 gives many opportunities for investigating the older strata along the eastern margin of the carboniferous beds. Trig. Station K. 32 has been erected on the highest summit of an extensive range of low hills made up of beds of micaceous schist and quartzite, the average strike of which is 296 degrees and with a steep dip to the south-west. The quartzite which forms the actual summit is nearly 100 feet in thickness and of a very white and sugary appearance; it contains a little mica in places. The general character of the rock suggests that the bed has been permeated by secondary silica. About three miles east of K. 32 is another conspicuous hill made up of a fairly coarse quartz-schist which dips at a high angle to the east and with approximately the same strike as that of the beds to the west. There are several sections between this hill and K. 32 showing the schists to be intersected by pegmatitic granite veins which are parallel to the dip (or the foliation) of the country. One vein contains a fairly large proportion of crystals of tourmaline which however do not attain any large size. Due north of K. 32 and the main branch of the Arthur River the flats expose both quartz and mica schist traversed by numerous lenticular quartz veins.

A very prominent quartz reef visible for great distances forms a high precipitous cliff overlooking a fine deep and apparently permanent pool on the northern bank of the river. A good section on the north bank showed the reef to be about 25 feet in thickness, encased in schist and to trend generally north and south. The reef can be followed by the eye across country for a considerable distance. The cliff sections indicate perfectly clearly that the reef has been very much contorted and has the appearance suggestive of its being a shear or thrust plane.

From camp at Bilyarra Pool on the Gascoyne a traverse was made as far as Trig. Station K. 31, and the staple formation consists of quartz and micaschist of the usual type intersected by quartz and granitic veins. The summit of the hill upon which the cairn has been erected is a large vertical quartz reef trending generally 260 degrees; the reef has considerable horizontal extent and has been faulted in a direction of about 323deg., with a horizontal

displacement of some hundreds of feet. Several long ridges to the westward are formed of white quartz reefs also.

Associated with the quartz and micaschist are beds of white crystalline limestone (marble): one bed about a quarter of a mile north-east of K. 31. is vertical, and has a general strike of 125 degrees. Some little distance to the west, about half or three-quarters of a mile, of K. 31, there is a very large development of this bedded marble [7546]. The marble is of a somewhat coarse grain and a greenish colour; the stone itself, if in a suitable geographical position, could doubtless be utilised for ornamental purposes; though many bands of it would prove much more valuable than others. As a whole the marble is fairly compact, making a smooth surface capable of receiving a high polish. Some portions of it, however, are of such a coarsely crystalline texture as would doubtless interfere with its use for highly ornamental purposes. The schists with which the marble is interstratified are pierced by granite (pegmatite) veins, but in no case did I see any such intersecting the marble itself. No opportunity presented itself of examining the whole of the area occupied by the marble.

There seems some reason to believe that these marbles have been subjected to a considerable amount of faulting; time however did not admit of any detailed mapping in the neighbourhood in order to arrive at its amount and other cognate points.

At Beelu Island, higher up the river, is a large quartz reef of considerable thickness crossing the island and the various channels of the river on an average bearing of 288 degrees. This reef as seen at Beelu Pool on the eastern bank of the river is not one thick vein of solid quartz but is merely a great mass of quartz about 120 feet thick, with one or two minor bands of schist, each of no great width. It may however be virtually regarded as a single quartz reef, with "horses" of country rock. This reef is traversed by certain vertical north and south joints, which are crossed with horizontal rectangular joints, the latter being often slightly slickensided and in some cases coated with a film of oxide of iron, about a quarter of an inch in thickness. The reef is of considerable horizontal extent and gradually peters out at either end.

Due west of Bilyarra Pool is a large development of quartz-mica-schist, intersected by bold quartz reefs of the usual type. The schists are also intersected by pegmatitic granite veins, which seem, in this locality, to be a very prominent feature in the geology, though they do not as a rule make very pronounced features on the surface, being largely composed of felspar, which readily lends itself to decomposition.

The rocks, therefore, which form the floor upon which the carboniferous rocks were laid down as exposed along the margin, between the Wooramel and the Arthur Rivers, consist of an extensive series of ancient metamorphic sedimentary rocks which have been

invaded by intrusive granite, in the form of pegmatite veins and quartz reefs in addition to much more recent greenstone dykes. The occurrence of the tourmaline-bearing pegmatite dykes in certain areas suggest the possibility of tin occurring in the vicinity.

THE COUNTRY BETWEEN BEELU POOL AND BANGEMALL.

(Geological Sketch Map, Plate I.)

Between Bilyarra Pool and Murkathadda, near Traverse Station N. 27 on the Gascoyne River, the rocks exposed consist of schist of the type prevailing to the southward.

Near Murkathadda Pool, however, the place of the schists is taken by a very coarse granite which forms a very prominent range on the eastern bank of the river. On the eastern bank of the river, near the camp, about midway between Traverse Stations N. 27 and N. 28, granite prevails, but about two miles distant it gives place to schist of the usual type, intersected with very many white quartz veins. The western bank of the river, opposite the camp, is the junction between a coarse porphyritic schist, which has a general east and west strike. The sections seem to point to the intrusive nature of the granite.

Leaving the camp on the river it was deemed expedient to travel generally north-eastward in the direction of the prominent hill named, from its shape, the Pyramid, and eventually the foot of the hills lying between it and the Lockier Range was reached. The highest summit of the range was ascended and was found to consist of a coarse granitic schist or gneiss, the foliation planes of which were inclined at a high angle to the south-west. The granitic schist or gneiss was intersected by several vertical veins of a very coarse pegmatitic granite, the average strike of which is north 50 degrees east. It is upon one of these dykes that the Mica Mine is situated.

The Mica Mine.—The locality at which a little work upon a mica deposit has been done lies in a range of hills due west of Reserve 699 on the Gascoyne River and between the Pyramid and the Lockier Range. On a clear day the mine can be seen from any commanding eminence, owing to the quantity of mica which has been raised and left lying on the surface, and which glistens brilliantly in the sunlight. A considerable quantity of work had been done upon the deposit, but judging from the condition of the workings many years must have elapsed since operations were in full swing. The mica deposit is a coarse vertical pegmatite dyke of about three or four feet in width, and trending generally east and west. The dyke had been opencut for some distance to an average depth of about 14 feet; it contained several "books" of white mica, but apparently none of any considerable size. A fairly large quantity of the mica had been raised and was left lying on the surface. Some portions of the deposit contained kernels or books of black mica, but not in any

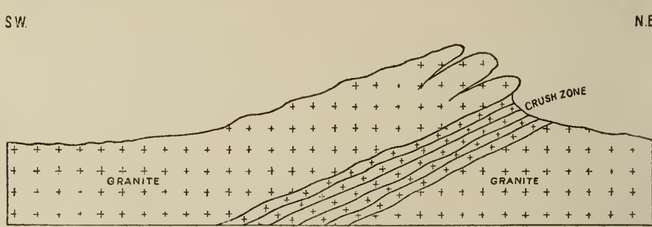
quantity. So far as can at present be seen the deposit seems capable of yielding a fairly large quantity of mica of a medium size, though its geographical position will for a long time to come place it beyond the reach of commercial enterprise.

There are several mica-bearing pegmatites in the neighbourhood some of which contain considerable quantities of tourmaline. One very prominent vein in the neighbourhood is of an exceptionally coarse variety, the quartz and felspar occurring in huge blocks, the former of which stand out in bold relief upon the hill top. The quartz is of a white sugary nature, which is entirely different to, and readily distinguished from, that of the ordinary mineral-bearing quartz reefs. These pegmatite dykes might under more favourable conditions be of some commercial importance.

The Lockier Range lies to the north of the Mica Mine; it was discovered in 1858 by Mr. F. Gregory, and named by him after Mr. Lockier Burges, one of the principal promoters of the expedition. Mr. Gregory in his report describes it as "a compact sandstone range resting on a granite base."

The range itself rises to a considerable altitude above the level of the surrounding country and is made up of a series of almost vertical quartzites, the general strike of which is north and south; such a dip as many of the beds possess is to the east. The rocks exposed at the foot of the range consist of granite and granitic gneiss, but the exact relation which these bear to the Lockier Range quartzites is not quite clear from any of the sections it was found possible to examine in the time at my disposal.

To the south-west of the range and about three-quarters of a mile distant from it is what appears to be a shear zone in the granite. The section exposed is shown in the drawing which forms Fig. 11.



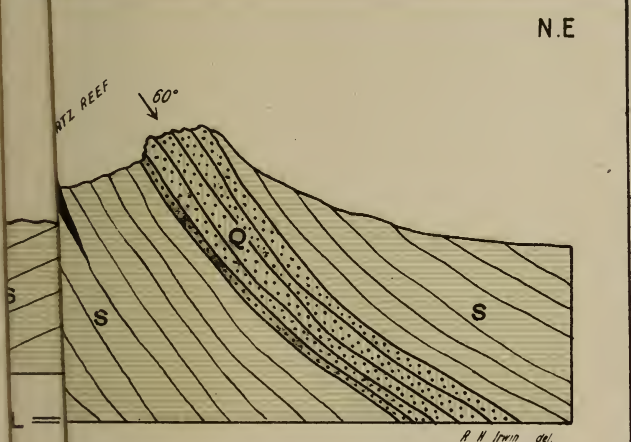
SECTION NEAR THE LOCKIER RANGE, GASCOYNE RIVER.

Fig. 11.

Leaving the Lockier Range the exigencies of travel necessitated the track in the direction of Bangemall being followed; the route taken lay to the north of what is shown on Lands Department Lithograph 78 (issue of 1905) as Bare Granite Rock.

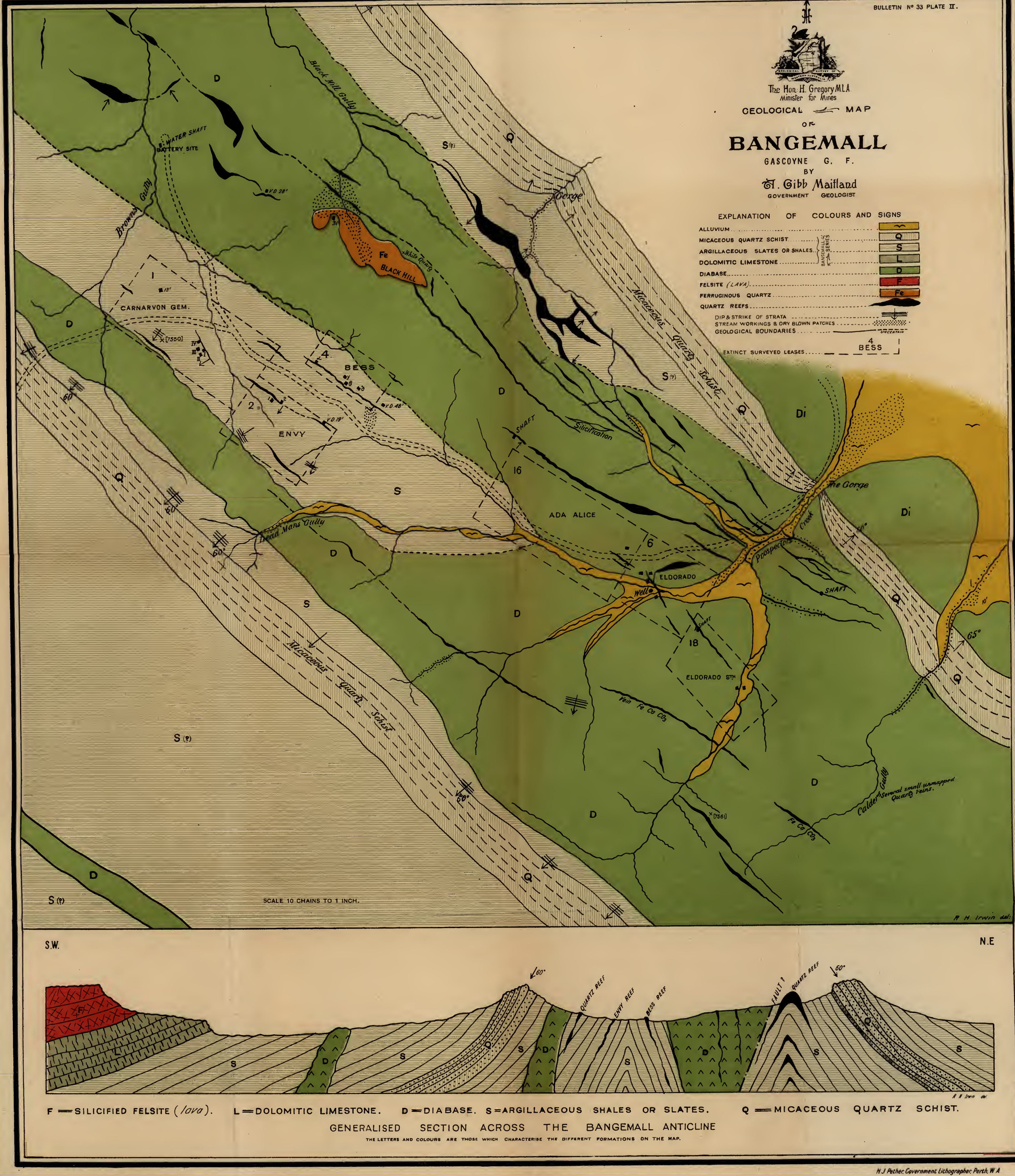
Bare Granite Rock is, as its name implies, a large bare hummock of granite which is visible for many miles in all directions. The whole of the country in the vicinity consists of granite and gran-

BULLETIN Nº 33 PLATE II.



CEOUS QUARTZ SCHIST.

H. J. Pether, Government Lithographer, Perth, W. A.



H. J. Pether, Government Lithographer, Perth, W.A.

itic gneiss intersected by large pegmatite dykes containing varying proportions of tourmaline and mica.

From camp near White Quartz Hill, due north of Bare Granite Rock, the track trended generally north-east, passing what is known as the Twelve-Mile Well (No. 2) on Reserve 7462, and had been carried over granite the whole distance. Many portions of the granite are intersected by crush lines which when viewed on the whole have an approximate parallelism.

Opportunity was taken of a good long spell of daylight after arriving in camp to examine the country in the vicinity. The beds exposed in the vicinity of the Twelve-Mile Well consist of very micaceous sandstones, etc. (in reality schists) inclined at high angles and intersected by numerous pegmatitic granite dykes, containing in many places fairly large crystals of tourmaline. Some of the tourmaline crystals are very much broken and twisted. From some of the higher ground in the vicinity the country to the south can be seen to be traversed by many large and persistent ice-like quartz reefs.

A day was devoted to an examination of the vicinity of Mount Phillips; from camp at the Twelve-Mile Well to the foot of the mountain, the rocks exposed were nothing but schists of the usual type. Some of the schists had a very granitic appearance, suggesting the possibility that they owed their origin to the squeezing of a granite.

The southern and western faces of Mount Phillips presented a bold vertical escarpment which formed a very conspicuous and picturesque object in the landscape. It was formed of a massive sandstone or quartzite which rested with a violent unconformity on the schists, etc., of the lower ground.

Opportunity was taken to make a more detailed examination of Mounts Phillips and Samuel at a later stage of the journey on the completion of the Geological Survey of Bangemall, and a description of the sections will be found on a later page, when their significance can be better understood.

Leaving the Twelve-Mile Well, Bangemall was reached on the 15th of June, where a stay of 29 days was made, during which a more or less detailed examination of the mines, etc., was undertaken.

THE BANGEMALL MINING CENTRE.

[With a Geological Map, Plate II.]

The Bangemall Gold Mining Centre is situated in the Gascoyne Goldfield about 270 miles from Carnarvon on one of the tributaries of the Lyons River, and about 30 miles west of Mount Augustus, one of the highest mountains in the State.

The field seems to have been discovered in the early part of 1896 by a small prospecting party fitted out by Messrs. Fenner and Baston, of Carnarvon. The efforts of the prospecting party were rewarded by the discovery of the Gem Reef.

The field, owing to its geographical situation and the want of the necessary machinery for gold extraction, has not produced any very large quantity of gold.

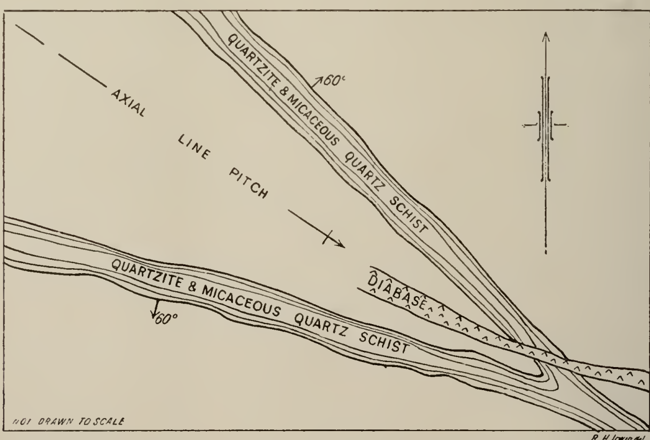
From the latest official figures available it appears that the district has yielded 268 ounces of alluvial and 237 ounces of reef gold, whilst the total yield of the Gascoyne Goldfield up to the end of December, 1908, is stated to have been only 505 ounces.

GENERAL GEOLOGY OF THE AREA.

When viewed broadly the geological structure of the area is fairly simple and the rocks exposed few in number. The solid rocks exposed consist of slates, limestones, quartzites, and igneous rocks, which are believed to belong to the older auriferous series as developed in many portions of the State.

The productive area of the field lies between two conspicuous bands of micaceous quartzschist and quartzite [**7549, 7564**] which trend generally north-west and south-east.

These two bands form the legs of a denuded anticlinal fold, and dip at an average angle of 60 degrees to the north-east and southwest respectively. There seems some good reason for believing this fold to have a decided "pitch" to the south-east. These two bands form very conspicuous serrated razor-backed ridges which trend for a considerable distance across country; they may be followed south-eastwards for some miles to a point fixed by the following magnetic bearings:—Mt. Augustus 110deg.; Mt. Samuel 164deg.; Mt. Phillips 185deg. At this point the two bands of quartzite intersect as shown in the sketch plan forming Fig. 12, which however is not drawn to scale.

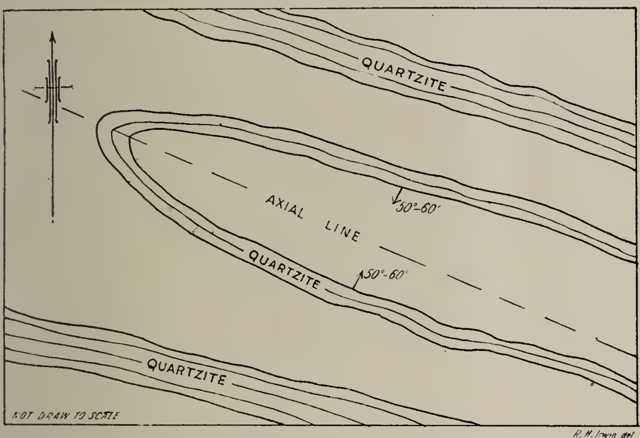


SKETCH PLAN OF THE SOUTH EASTERN END OF THE BANGEMALL ANTICLINE.

Fig. 12.

The point of intersection lies of course some considerable distance beyond the limits of the geological map of Bangemall. The beds at the intersection are vertical and are pierced by a diabase dyke.

In the vicinity of the Twelve-Mile Camp, distant, as the name implies, about 12 miles to the north-west, along the strike of the country, the succession of strata is identical with that at Bangemall itself. The "range," which is the north-western extension of that at Bangemall, consists of very siliceous slate, some bands in which are very much contorted and puckered. In this locality the quartzites are arranged in the form of a synclinal fold, as shown in the sketch plan which forms Fig. 13.



SKETCH PLAN Nr NORTH EASTERN END OF THE BANGEMALL ANTICLINE

Fig. 13.

These two sections are of importance, throwing as they do such a considerable light upon the structure of the district and its bearing upon the possible extent of the mineral resources of what may for convenience be called the Bangemall auriferous belt.

Some little distance to the north-west of the water shaft on Brown's Gully, the ground rises fairly rapidly and in consequence of the pitch of the axis or axial line of the Bangemall anticline, lower beds are brought up to the surface, the most conspicuous being the siliceous quartzites, which form a ridge, upon which the highest summit in the district is situated. The outcrop of this band of siliceous quartzite forms a V, somewhat after the fashion of that occurring at the south-eastern extremity of the belt. (Fig. 12.)

A generalised section across the field in a direction of north-east and south-west shows the structure of the field so far as may be deduced from the evidence available; the section, however, pretends to no more than a very probable interpretation of the dis-

position and arrangement of the beds. The section, in conjunction with the map shows that what may be called a modified anticlinal fold which traverses the field from end to end, and the auriferous reefs outcropping in different localities bear an important relation to the folding which the beds have undergone.

Not much work has been done underground in the way of cross-cutting, hence there is no opportunity of carefully studying the folding, etc., though it is very probable that a good deal of what appears to be, at present, the dip of the strata, may really be cleavage induced by the pressure to which the beds have been subjected.

Beneath the micaceous quartzschist which forms both legs of the anticline there are several varieties of rocks exposed; the principal one being a diabase [7561] which seems to have undergone a considerable amount of alteration to an extent which has virtually obliterated its original structure. As followed south-eastwards along the axis of the anticline, it is seen that this rock is intrusive. (Fig. 12.)

A thin band of black spotted rudely cleaved rock outcrops in the vicinity of the Gem, G.M.L. 1. The matrix is very dense, whilst the minerals developed therein are dragged out into long eye-shaped lenticles. According to Mr. Thomson's microscopic observations, given in full in the Petrological Notes on pp. 159, it appears that the rock is much altered and its original nature obscure; it is however very probable that it forms one of the interbedded lavas or sills associated with the beds of the Bangemall series.

The greenstones of the field are traversed by two well-marked veins of ankerite (carbonate of lime, magnesia, and iron). The most important of these veins has an outcrop of about 25 chains in length and crosses the headwaters of Prospector's Creek, near the southern angle of the Eldorado South lease, G.M.L. 18. A second parallel vein crosses the head of Calder's Gully, about 30 chains above the gorge.

Important evidence as to the structure of the field seems to be furnished by the numerous ice-like quartz reefs, which make one of the most prominent features in the north-eastern portion of the belt.

One of the most persistent of these veins is that which first makes its appearance in the fork at the head of Black Hill Gully, and loses itself beneath the alluvium of one of the smaller creeks which falls into Prospector's Creek about 10 chains above the gorge. As indicated on the map, the vein has a maximum width of about 120 feet, and in one or two places rises to a considerable height above the surface; where this vein is crossed by the small creek, which cuts through the micaceous quartzschist, it is to be seen that either wall of the quartz dips at a fairly steep angle to the north-east and the south-west respectively.

As followed along the outcrop to the south-eastward the reef varies greatly in size and form and diminishes to mere threads of quartz. The reef forks and the two extremities are in one place

about 500 feet apart. All the available evidence seems to point to the fact that this quartz vein is merely a saddle reef, which has been laid bare by denudation and that the two small veins which form the south-eastern end merely represent the legs of the saddle.

As may be seen by an inspection of the Geological Map of Bangemall the alluvium which occurs in the bottoms of many of the valleys has been worked for the gold it contains, and in two special instances, viz., Prospector's Creek and the gully to the north-east of Black Hill, it is noteworthy that it is in close proximity to the apex and the legs of the saddle that the alluvial gold has been derived. About 60ozs. were obtained from the alluvium in the bed of the creek to the north-east of Black Hill: the extent to which the deposit has been worked is indicated by stippling on the Geological Map.

The alluvium of Prospector's Creek has also been more or less extensively worked below the Eldorado lease. About £1,000 worth of gold was obtained at the spot where the creek crosses the bar of micaceous quartzschist. The gold was found just above the bar, where it had evidently lodged in its downward passage; a fair quantity was obtained from the top of the bar itself, but no exact record of the number of ounces seems to have been kept. The alluvium below the gorge varies very much in thickness, and so far as work has at present been carried it attains a maximum of eight to ten feet. In one of the old workings the bottom, upon which the alluvium rests, dips to the eastward away from that of the channel of the main creek, indicating that the watercourse has shifted its position upon more than one occasion.

A good deal of desultory work has been done on the alluvium of Calder's Gully, more especially in that portion of its course below the gap, by which it passes through the micaceous quartzschist ridge indicated on the map.

The width of this belt of quartzschist is about 500 feet. Some distance back from the creek the thickness of the alluvium, as shown in the old workings, is about 10 feet, whilst its width fluctuates within very wide limits. At the gap and for some distance below it the alluvium consists largely of fragments of quartzschist, covering a very thin layer of wash. There does not seem to have been any record kept of the quantity of gold obtained from this gully. There are not the same number of reefs in the watershed of Calder's Gully as in the others to the westward, hence really very little work has been done in the gully.

The quartz reefs in the area more immediately surrounding the neighbourhood of Bangemall are, as may be seen by the Geological Map, very numerous. They are all confined to a belt about 60 chains in width, exhibit a marked parallelism, trending in a direction of north-west and south-east.

They vary very much in thickness, from that of a sheet of paper up to 120 feet. It is however only upon six of them that any mining work has been done; so far as was possible all accessible workings have been visited and careful notes made of what could be seen underground.

The most important feature in the whole field is the recognition of the saddle reef nature of the auriferous quartz veins, and while up to the present time it is obvious that no very valuable reefs have been opened up, it is possible that further search along judicious lines may lead to further discoveries.

THE QUARTZ REEFS AND MINES.

The following is a detailed description of such of the quartz reefs exposed in the workings which were open to my inspection.

Black or Ironstone Hill forms the highest and perhaps the most conspicuous of any of the hills within the limits of the area mapped. The hill has a maximum length in a north-east and south-west direction of 1,200 feet and a width of 30 feet at right angles to this. Its south-western face, which overlooks the headwaters of Brown's Gully, presents a fairly bold escarpment, which makes a prominent feature in the landscape.

The hill is made up of a large or rather a series of quartz reefs which trend in the direction of the general strike of the country, namely, north-west and south-east.

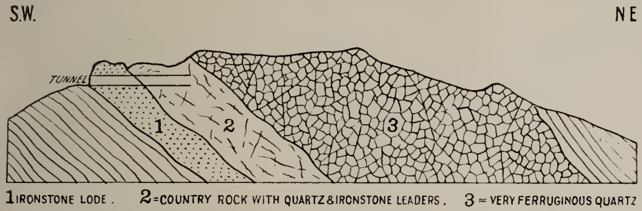
With one single exception the quartz reefs are remarkably ferruginous; there are all gradations from [7556] a pure white quartz reef; to another [7557] in which the quartz is brecciated and the interstices filled with oxide of iron which forms a cementing medium. In hand specimens the quartz would pass for a very ferruginous quartzite. This variety graduates into [7558] a dense limonite with fragments of white and glassy quartz, and finally into [7559] a frothy cellular limonite, containing a little hematite; whilst many of the interstices or vughs are either coated or filled with chalcedony.

Samples of the white quartz [7556] and the dense limonite [7558] when assayed in the Survey Laboratory yielded a minute trace of gold, whilst the other two varieties [7557, 7559] proved to be barren.

A very large area of the hill on its northern slopes had been dryblown and I was informed by Mr. Macnamara that about 60ozs. of gold had been obtained from the summit of the hill and about 100ozs. from the patch on the slopes to the north-west. The area of the dryblown patch has been accurately indicated on the Geological Sketch Map. This gentleman also showed me a fragment of ironstone stated to have been obtained from the summit of the Ironstone Hill which yielded, on being dollied, about 6ozs. of gold. Two of the fragments [7560] contained free gold; the fragment shown to me

was in every respect identical with the two ores from the summit [7558, 7559] and contained kernels of solid pyrites.

An attempt had been made to do a little exploration work upon the southern slopes of the Ironstone Hill, just below the summit. A tunnel had been driven in a direction of north 45 degrees east for a distance of 53 feet and exposes an interesting section, Fig. 14.



SECTION ACROSS IRONSTONE (BLACK) HILL, BANGEMALL

Fig. 14.

Carnarvon Gem, G.M.L. 1.—The Gem is the most westerly of all the leases on the Geological Sketch Plan, Plate II.

Early in 1896 a prospecting party of five persons fitted out by Messrs. Fenner and Baston, of Carnarvon, discovered the Gem reef, and in June, 1896, a twenty-four acre lease was applied for by Mr. Geo. Baston.

The mine passed, in 1897, into the hands of a syndicate of 12 persons under whose auspices some 200 to 300 tons of ore were raised at a cost it is stated of £1,045. A small battery was erected but for some reason or another it proved a failure. In 1898 about 400 tons of stone were raised at a cost of £858, thus leaving a total of about 700 tons of ore for crushing.

It was believed that 250 tons of this—picked stone—would yield 2 to 3 ozs. of gold per ton, whilst the remaining 450 would return an average of about an ounce to the ton.

Four trial crushings were put through a battery erected by a company for public crushing in 1898. Thirty-eight tons of the poorer stone are stated to have yielded about 2dwts. per ton; a 41 tons parcel of the picked stone, which included 5cwts. of specimen stone, yielded in all 48ozs. of gold; a third parcel of 56 tons gave a total of 34ozs., and a fourth 43ozs. from 46 tons. In other words 143 tons of the picked ore gave by battery treatment 125ozs. of gold.

Owing to the high cost of crushing and carting it appeared that at the time the mine was worked, it required stone yielding at least an ounce of gold per ton to meet bare expenses, providing the ore could be raised at 23 shillings per ton.

It appears that about £3,000 have been spent on the mine, which gave a net return from the gold sold of about £150.

The bulk of the work, however, has been concentrated near the central portion of the lease and a good many shafts sunk.

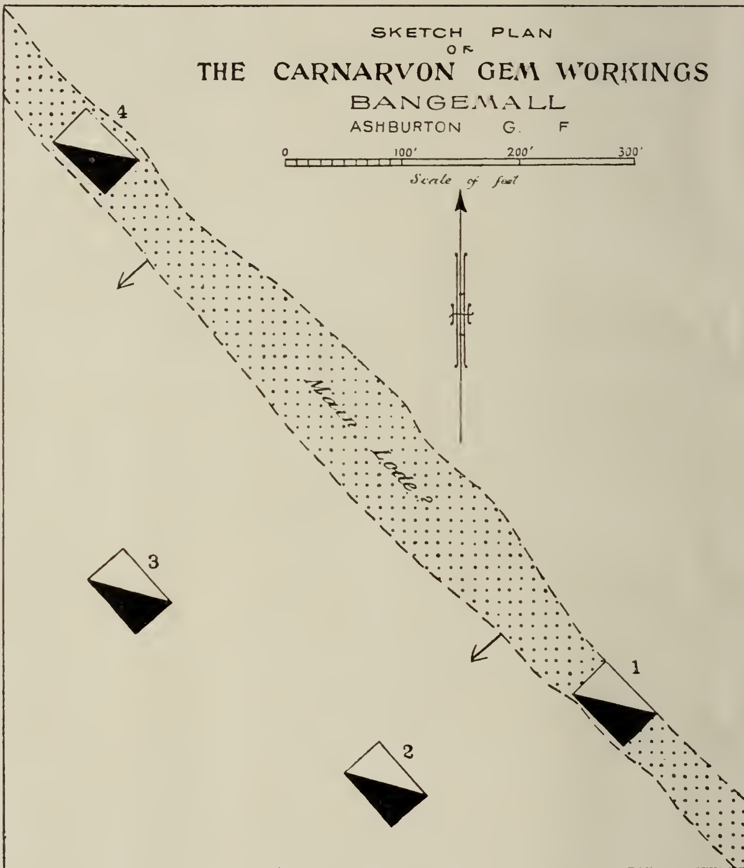


Fig. 15.

There being no plan of the workings it is almost impossible to give any intelligible description of the workings or the precise nature and character of the deposits.

It seems, however, as though shafts 1 and 4 had been sunk upon the same deposit, which consists of a network of leaders upon what has every appearance of being a crush line. The stone in the dumps of the shafts 1 and 4 contains free gold, oxide of iron, pyrites, and carbonate of lime.

No. 2 shaft has been carried down to a vertical depth of 60 feet and a drive put in in a direction which, owing to its being full of water, could not be ascertained. No. 3 shaft is 41 feet deep.

It is stated that:—

"The reef is irregular in its size, being 12 feet thick in places with an average of 6 feet . . . . Associated with this reef is the possibility of larger reserves in the footwall country due to the lacing and interlacing of flat leaders, which are much above the average value of the main reef; one of these near the surface has been worked to a distance of 50 feet, at which point it turned vertical, it is 2 feet 6 inches wide. It is developed by sinking 30 feet and driving 15 feet, this is continuing strong underfoot . . . . ."

It does not appear that this mine possesses any defined reef, and payable ore only occurs in irregular patches, a condition of affairs which naturally tends to make mining not only difficult but expensive.

It is quite possible that the irregular flat and other leaders which seem to be in some way associated with what may be called the main reef are in reality merely spur veins which have some connection with what are believed to be the legs of a saddle reef. An inspection of the Geological Map and Section shows that the Envy and the Boss reefs dip in opposite directions and may merely represent the remnants of a saddle reef.

The following table, prepared from official data, gives the output of the Gem mine in fine ounces:—

Table showing the Yield of the Carnarvon Gem G.M.L. 1.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Rate per ton.
		tons.	fine ozs.	fine ozs.
1897 ..	Carnarvon Gem G.M.L. 1 ..	1·35	6·17 *6·22	4·57
1899 ..	Do. do. ..	175·00	146·06	·83
	Total	**176·35**	**158·45**	·89

* Dollied.

Envy, G.M.L. 2.—This lease, which embraces an area of 12 acres, was originally taken up in June, 1896, by Mr. Arthur Gors, on behalf of a syndicate comprising fourteen members.

A well-defined quartz reef with an outcrop of 500 feet in length traverses the southern portion of the property at about 100 feet from the south-western boundary. The reef is a milk white quartz [7553] containing veins of oxide of iron up to an inch in thickness; in one spot near the eastern end of the outcrop it passes into an almost pure ironstone [7554]. A good deal of chalcedony has been deposited in the quartz reef. This reef has been opened out in one place and attains a thickness of about three feet; as measured on the surface it underlays at an angle of 60 degrees to the south-west.

What is without doubt the main Envy reef traverses the northern boundary of the lease not far from and approximately parallel to the boundary.

The quartz is identical in its physical characters with that forming the rest of the reefs on the field, and is in places exceptionally ferruginous, being nothing but oxide of iron. The reef has been opened up by three shafts in the position indicated on the Geological Map, Plate II.; none of these, however, were accessible to me.

Shaft No. 1 sunk some little distance back from the outcrop gave when a tape was lowered 30 feet as its depth; the shaft however had a slight underlie to the south-west, but its total depth is unknown to me, nor could I ascertain this when in the locality.

There are no returns of any crushings from this reef.

Boss, G.M.L. 4.—This six-acre lease was originally taken up by Messrs. Hubble, Schumann, and Young, in May, 1896.

The Boss reef has a fairly well-defined outcrop and traverses the whole of the south-western portion of the lease, at an average distance of about 30 feet from the southern boundary of the property. The total length of the outcrop of the reef is about 1,000 feet.

So far as may be gathered from a careful inspection of the surface, the quartz which forms the reef is on the whole very white and vitreous, and somewhat of an ice-like character; it passes as do most of the reefs on the field by almost insensible gradations through very cavernous ferruginous quartz into pyrites [7567]; the latter forming kernels in the limonite, which makes up the bulk of the oxidised ore. The limonite and the pyrites are in places filled with cavities which are lined with secondary silica; in some cases free gold is showing.

At a point about 80 feet east of the western angle of the lease is a shallow shaft, 20 feet deep, put down on an underlay of 45 degrees. Some desultory work has been carried out on a small though somewhat irregular vein of quartz which varies from one to 12 inches in thickness; this is the Boss reef as showing at this end of the ground. At about fifteen feet below the surface the reef bends over in the shaft as though it had been folded. No other work appears to have been done on the vein at this locality beyond sinking the shaft.

The reef can be followed along the surface to a point about half-way along the southern boundary where it has been opened out by means of a shaft (B). The shaft has been sunk vertically for a depth of 13 feet to the main reef, and has been carried down on an underlay of between 40 and 50 degrees in a direction of north 30 degrees east. The reef can be followed down the underlay for a distance of 23 feet, with an average thickness of about 12 inches; at this point a short drive has been put in south-eastwards along the reef, but no variation in its character can be noticed. The hanging wall, however, in this drive is very powerfully slickensided and

underlays at an angle of about 50 degrees northwards. The shaft has been continued on the dip for some further distance, but being inaccessible its total depth is not known to me nor the behaviour of the reef ascertainable.

A block shaft (8) 46 feet north of this has been sunk to a measured distance of 51 feet at a point 50 feet from the outcrop of the Boss reef; it was however inaccessible and no details are obtainable. Judging from the debris however in the dumps the sinking was through a fine-grained greenish sandstone. It is stated that 200 ozs. of gold have been obtained from the outcrop of the reef between shafts.

Another block shaft (8) has been put down at a point 200 feet south-west from (8). This shaft was also inaccessible, but a tape lowered gave its depth as being 46 feet. The sinking was identical with that in (B).

Parallel to the main Boss reef is another of a similar character though much shorter about 40 feet to the north of it; and is exposed in a costean 100 feet west of shaft (B). No work, however, has been done upon it.

A short quartz vein trending roughly parallel to the main reef outcrops at the north-east angle of the lease as indicated on the Geological Map.

A fair amount of dryblowing has been done at the south-east angle of the lease, but with what result there is no very authentic account to be obtained. Any gold, however, is likely to have been derived from the Boss reef.

The Boss reef has the same general characteristics as that in other portions of the field and the geological conditions are about the same. Owing to a variety of causes coupled with the small amount of exploration work done upon the veins there is no information as to either the exact nature or the behaviour of the ore shoots.

There is a little stone round the dumps of the outcrop shafts but there does not appear to have been much stone taken out from the mine. There seem to be good sound reasons for believing that the Boss reef forms the north-eastern leg of a saddle reef which has been laid bare by denudation. The following table gives the yield of this reef so far as can be ascertained from official data:—

Table showing the Yield of the Boss G.M.L. 4.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Rate per ton.
		tons.	fine ozs.	fine ozs.
1899 ..	The Boss G.M.L. 4	19·35	24·70	1·27

Eldorado, G.M.L. 6.—This ten-acre lease was originally taken up by Messrs. Ayliffe, Ayliffe, and Fenner in July, 1896. It has been the scene of a good deal of work, and upon it there have been sunk six shafts.

As may be seen by an inspection of the Geological Map the lease is traversed by a portion of Prospector's Creek which is flanked by a shallow alluvial deposit of considerable width.

A well-defined and large white quartz reef makes a bold outcrop on the surface and occupies that portion of the lease which lies between the creek and the road; as it nears the creek the reef passes into ironstone and changes its course almost due south to its intersection with the fissure which carries the Main Eldorado reef. This latter reef outcrops in the bed of Prospector's Creek close to shaft 2, which is now used as a well, and seems to run at an oblique angle to the rest of the reefs on the field, as an inspection of the geological map shows.

The southernmost shaft (No. 4) on the line has, I understand, been carried down to a vertical depth of 23 feet, and pierced the Eldorado reef at fifteen feet, where it is stated to have been but thin. The shaft, however, was inaccessible.

The main or vertical shaft, No. 4, used as a well, passed through the reef at 35 feet though the total depth of the shaft is 55 feet. Water was however standing in the shaft to a height of 37 feet below the surface, hence the workings are inaccessible. Free gold may be seen in the stone lying in the dump; the quartz is of the ferruginous type common to the reefs of Bangemall; portions are highly brecciated, the interstitial cementing matter being oxide of iron.

The next northerly shaft (3) has been carried down 16 feet vertically, at which point it intersected the reef and thence along the underlay of the reef for a further distance of 35 feet. There is 15 feet of water standing in the bottom of the shaft. As seen in the shaft the reef is very well-defined and of the usual ferruginous nature. As measured in the shaft the underlay of the reef is from 45 to 50 degrees to the south-west.

In No. 1 shaft the Eldorado reef was met with at 35ft. from the surface and water now stands at 39 feet, thus preventing anything being seen.

The most northerly shaft (No. 6) is 28 feet deep and the reef is said to be represented only by a thin graphitic seam.

No. 5 shaft, sunk on the wrong side of the reef, had been carried down 15 feet. It is very probable that the reef outcropping near the south-east angle of the lease is a further extension of the vein in this direction.

In a communication to the Minister in February, 1903, in connection with an application for a subsidy under the terms of the Mining Development Act the manager, Mr. T. Bennet, wrote:—

Eldorado has three shafts to water level, viz., 65 feet, covering a distance of 150 feet along the reef; these are connected up by a drive at the bottom level. . . . . The reef for the full length of the drive is 6 feet wide between two well-defined walls, and shows every probability of further satisfactory development—the average width from surface to 65 feet level is 4 feet. The course of the lode is north and south, and underlying west at about 50 degrees.

Table showing the Yield of the Eldorado G.M.L. 6.

Year	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Rate. per ton.
		tons.	fine ozs.	fine ozs.
1899 ..	Eldorado G.M.L. 6	**41·00**	**41·56**	**1·01**

Synoptical Table showing the Yield of the Bangemall Reefs up to the end of 1908. (From official figures.)

Name of Reef.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	fine ozs.	fine ozs.
Boss G.M.L. 4	19·35	24·70	1·27
Carnarvon Gem G.M.L. 1	176·35	158·45	·89
Eldorado G.M.L. 6	41·00	41·56	1·01
Sundry Claims (Black Hill)	..	12·29	..
Alluvial	..	268·27	..
Total	236·70	505·27	2·13

THE COUNTRY IN THE VICINITY OF BANGEMALL.

(Geological Sketch Map, Plate I.)

Having completed an examination of the more immediate vicinity of the workings at Bangemall, opportunity was taken of making a few traverses in the district with the object of arriving at a much better understanding of its salient structural features.

The neighbourhood of the Government well on Reserve 7462* afforded a good opportunity of investigating the strata. The country consists of very micaceous sandstones, etc. (schists) inclined at high angles and intersected by dykes of pegmatitic granite. These

* Lands Department 300 chain Lithograph No. 78.

pegmatites in many places contain fairly large quantities of tourmaline, some of which are broken and twisted.

A little distance to the south of the well the country was underlaid by granite, which seemed to intersect the old sedimentary series. The granite is traversed in many places by numerous crush lines. From the higher elevations in the neighbourhood the country to the southwards was seen to be traversed by many large ice-like quartz reefs of what may be called the Gascoyne River type.

A careful examination of many of the sections renders it highly probable that the high inclination of the old sedimentary rocks represents not dip but merely lines of cleavage.

Between the well and the foot of Mount Phillips the staple formation consisted of schists; many of which had a decided "granitic" look, as though their origin resulted from the squeezing and crushing of a granite.

In order to examine the sections visible in the vicinity of Mounts Phillips and Samuel, camp was pitched at a small rockhole in a creek rising in the saddle between the two mountains and flowing south.

The rockhole is in granite which is traversed by several parallel quartz reefs, some of which are of considerable thickness. These large quartz reefs have a general trend of north 50 degrees east.

The southern face of Mount Phillips presents a bold escarpment to the south and west, some hundreds of feet in height, and is made up of fine conglomerates, quartzites, etc., dipping at a gentle angle to the northwards. As seen in the escarpment of the southern face of the mountain the floor of ancient crystalline rocks upon which the sedimentary series rests has an extremely uneven surface.

At an altitude of 200 feet above the camp the southern face of the mountain (Fig. 16) is flanked at the base with a deposit 10 to 12 feet thick, of a somewhat gritty ferruginous sandstone dipping at a low angle southerly; it is evidently a consolidated talus deposit.

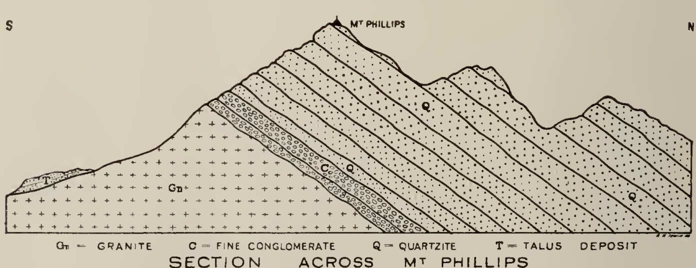


Fig. 16.

Mount Samuel is a razor-backed hill, distant about 300 chains south-east from its larger neighbour, Mt. Phillips, and by aneroid measurement 1,090 feet above the camp at the rockhole.

Fig. 17.

The base of Mount Samuel as approached from the south consists of granite intersected by quartz reefs and greenstone veins, upon which rest false bedded grits and quartzite, dipping at a fairly steep angle to the north. One or two of the beds of quartzite are so fine-grained and permeated with secondary silica as to similate very closely interbedded quartz veins.

There are no conglomerates showing at the base of the series as seen in any sections it was possible to examine at the time at my disposal.

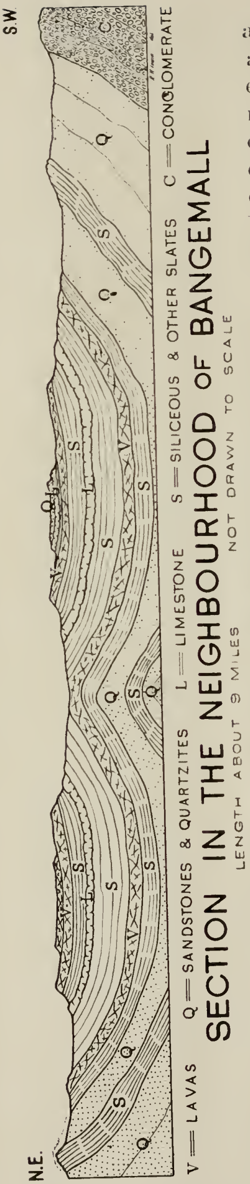
The boundary of the sedimentary rocks of Mount Samuel, which are continuous with those of Mt. Phillips, can readily be followed by the eye for about two or three miles to the south-east, when it loses itself in the flat country.

From the summit of Mount Samuel as seen through a pair of powerful binoculars, the country to the southwards seemed to be pretty well all granite, traversed by many prominent and well-defined quartz veins, whilst Mount Augustus was seen to be made up of bedded rocks dipping southwards, thus forming a large synclinal trough of which the Mounts Phillips and Samuel beds formed the southern side.

On the north side of Mount Phillips and distant about a mile from it is a razor-backed ridge with a prominent summit, known as Little Mount Phillips.

The ridge is made up of nearly vertical beds of a coarse boulder conglomerate, which have a general strike of 303 degrees; these beds, as may be seen in the section (Fig. 17), form the base of the Bangemall Series. The boulder conglomerate is overlaid by sandstones, quartzites, siliceous shales (or slates) and basic lavas.

Fig. 18.



Camp was pitched at a water hole about four miles east of Bangemall on a well-grassed flat, in such a situation as enabled the surrounding country to be readily examined. The situation of the camp is a little distance to the north-east of the intersection of the two bands of micaceous quartz schist shown in Fig. 12 and referred to on page 31 of this report.

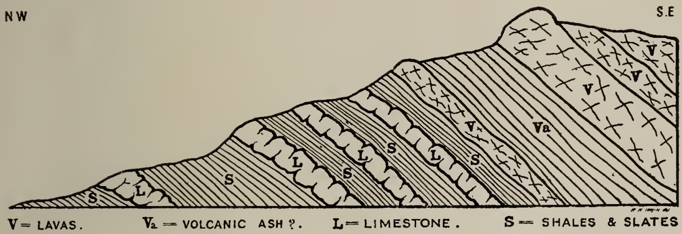
After crossing the flat valley of Enrama Creek, near which the camp was pitched, a traverse in the direction of Little Mount Phillips was made, and the first beds met with were the coarse basic lavas (Fig. 18) well shown in a narrow gorge through which the stream draining the tableland had carved its way. This gorge shows the dip of the lava at this edge of the tableland to be to the southwards. The central portion of the tableland which was about a mile in width, was covered with a thin deposit of lateritic iron ore. The dip of the lava on the southern lip of the plateau was to the north, thus indicating that the beds were arranged in the form of a shallow synclinal trough. The beds beneath the lava and outcropping between there and Little Mount Phillips consisted of siliceous and other slates, sandstones, quartzites and fine conglomerates all forming part of one and the same geological series.

The section at Mount Phillips shows the basal beds of the Bangemall beds.

Further sections in the vicinity of the camp show a series of unfossiliferous limestones associated with the quartzites, etc.

The section (Fig. 18) which has not been drawn to scale, has been compiled from the exposures visible in several traverses made in the neighbourhood. The whole series of strata bears a striking resemblance to that of the Hamersley Range to which a reference is made on a later page.

About twelve or fourteen miles to the north-west of the Bangemall workings a little desultory prospecting has been carried out in the past, but at the time of my visit operations were at a stand-



SECTION ABOUT 4 MILES SOUTH OF BANGEMALL.

Fig. 19.

still and the place was deserted. The succession of strata is identical with that at Bangemall, consisting of sandstones, quartzites, slates, and igneous rocks, with a few quartz reefs, some of which are of a fair size. These have an average bearing of 303 degrees.

A few shafts have been sunk to a shallow depth upon a fairly well-defined reef of that ferruginous type as developed at Bangemall, but owing to the condition of the workings access could not be obtained underground. The reefs in this locality however are not nearly so numerous as those further to the south-east. The quartz reefs of this neighbourhood form part of the same auriferous belt as that in which the deposits of Bangemall are situated.

Some miles to the northward of the Twelve-Mile Well, at which camp was pitched, the limestones associated with the Bangemall beds were exposed in many of the flats.

THE COUNTRY BETWEEN BANGEMALL AND MOUNT BLAIR ON THE ASHBURTON RIVER.

[Geological Sketch Map, Plate I.]

On the completion of the investigations at Bangemall and its vicinity it was decided to cross the Barlee Range, via Mount Augustus and Coorabooka Gap, to the junction of the Wandarry Creek and the Ashburton River at Mount Blair, with the object of examining the auriferous deposits of Soldier's Secret and Mount Mortimer. This traverse enabled a fairly complete section of the Bangemall beds to be obtained and the area they occupied to be more or less accurately defined.

Mount Augustus, one of the most conspicuous heights in this portion of the State, lies on the southern bank of the Lyons River, some miles above its junction with the Frederick River. The moun-

tain is the culminating point of a long ridge about five miles in length, trending generally north-west and south-east, with an average width of about two miles in a direction at right angles to this. It rises on all sides from the level plains, by which it is surrounded and forms one of the most conspicuous objects in the landscape, visible for many miles in all directions. The upper portion of the northern face is formed of an almost vertical escarpment, which extends across the greater portion of its length and is some hundreds of feet in height.

THE NORTHERN FACE OF MOUNT AUGUSTUS.

Fig. 20.

It appears that Mount Augustus was named on the 31st of May, 1858, by F. T. Gregory after his brother, Augustus, at that time leading the expedition in quest of the remains of Dr. Leichardt. The mountain was first ascended on the 3rd of June of that year and estimated by aneroid to be 3,480 feet above the sea level; the barometer reading on the summit 26.10 inches. No description, however, is given of the mountain by Mr. F. T. Gregory, which is all the more remarkable seeing that it is one of the most conspicuous and important in this portion of Western Australia.

The summit, upon which a Trigonometrical Survey Cairn has been erected, is situated on a second escarpment (Fig. 21) which rises to a height of about 300 feet above the top of the main front.

According to a communication received from the Surveyor General (29-9-09) it appears that the altitude of this station was determined by Sir John Forrest in 1882 as 3,580 feet above the sea level, which is 100 feet more than that determined by Mr. Gregory

twenty-four years earlier. My own observations made in July, 1907, with two Casella aneroids were as follows:—

	In camp, 8.30 a.m.	Summit at noon.
Aneroid 8390	28.28in.	25.94in.
Aneroid 8391	28.24in.	25.92in.

The Government Astronomer at my request was good enough to work out, by comparison with the nearest mercurial barometer, the altitude of Mt. Augustus from these data and gives it at 4,054 feet above sea level, or 474 feet above that determined by Sir John Forrest. No temperature observations were unfortunately possible owing to a breakage of my only thermometer.

The Government Astronomer's communication in connection with this estimate reads as follows:—

"From the weather map I consider that the barometer at Mt. Augustus, reduced to sea level at 8 a.m. of 1907, July 29, was 30.03; this is probably correct within 0.01 or 0.02. I assume from various sources that it fell 0.08 between 8 a.m. and noon, making 29.95 at noon. The temperature is more uncertain, but I have compared records along the coast with Wiluna, Peak Hill, and Cue, and assume 8 a.m.—55 deg., noon—57 deg. From these data I have computed the height of camp—1676 feet. This will be vitiated by any error in aneroid and temperature. Difference between Camp and Trig., 2354 feet, making height of Trig. 4030 feet. This (*i.e.*, the difference between Camp and Trig.) has the error due to aneroid eliminated, but is subject to assumed fall of 0.08 between 8 a.m. and noon, and to any error of temperature. Height of Trig. determined from aneroid (considered correct) and assumed noon reading corrected, at sea level—4079 feet. From these I should take the mean—4054 feet. Of course any aneroid affects both height of camp and height of Trig., but not difference—2354 feet.

An examination of the northern face of Mt. Augustus shows that it is fashioned in the form of a sharp monoclinal fold, the beds on the northern limb dipping at an angle of about 40 degrees to the north and those on the southern limb 25 to 30 deg. to the south.

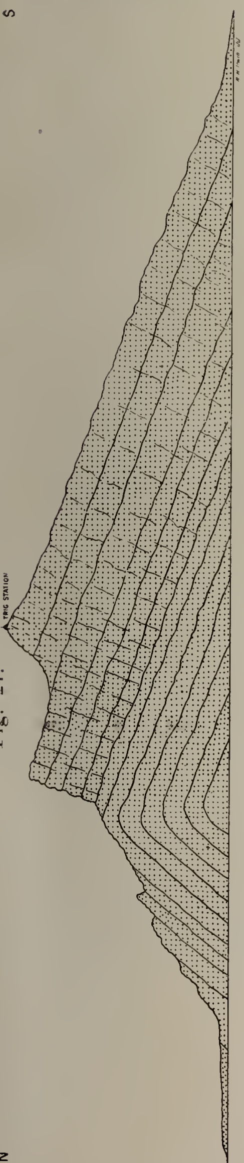


Fig. 21.

SECTION ILLUSTRATING THE STRUCTURE OF MOUNT AUGUSTUS, LYONS RIVER, GASCOYNE. C. F.

The beds of which the mountain is built up are composed of gritty conglomerates containing in places pebbles of quartz, mica (or sericite) schist, and a very dark rock which looks like a black micaschist. In certain isolated localities the beds are traversed by thin vertical quartz veins and in many parts some of the more gritty and felspathic beds have been eaten out into large caverns. The general trend of the Mount Augustus anticline is generally north-west and south-east, whilst the pitch of the fold is to the south-east also.

COORABOOKA GAP, LYONS RIVER.
Fig. 22.

About a mile and a-half to the north of our camp on the Lyons River, near the boundary between 67/889 and 67/461, is a very long low ridge made up of quartzite with a southerly dip.*

* Lands Department 300 chain Lithograph 78.

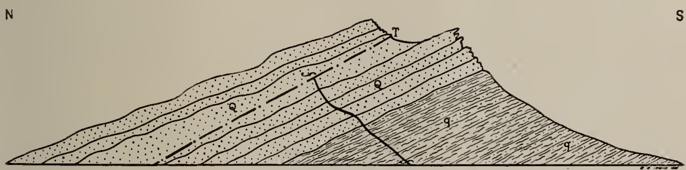
As viewed from the summit of Mt. Augustus the whole of the country visible seemed to be made up of bedded rocks, forming part of the same series as that which made up the staple formation of Bangemall; whilst on the divide between the Lyons and the Ashburton there seemed to be a series of horizontal strata, which may form the eastern extension of the Barleè Range.

From our camp at Mount Augustus we returned northwestwards about 10 miles along the main Bangemall road and camped at a well in the bed of the Lyons River. This well formed the starting point for our crossing the divide between the Lyons and the Ashburton Rivers. About five and a-half hours' travelling over fairly level country brought us to a windmill erected on a well on Coorabooka Creek. The strata pierced in the well consisted of sandstones and shales, which, from what could be seen in the bank of the creek, dipped south at a fairly low angle.

From the windmill the strata exposed as far as the Coorabooka Gap consisted of alternations of sandstones, quartzites, and interbedded volcanic rocks of the Bangemall type. At the gap these beds are conformably overlaid by thick massive quartzite which dips in a northerly direction at about 25 degrees.

The Coorabooka Gap is very picturesque (Fig. 22) and is flanked on either side by perpendicular cliffs of quartzite which rise to a height of about 500 feet above the level of the creek. The gap is carved out of a very long range which, as viewed from the south, makes a very bold feature in the landscape owing to the prominent escarpment of the quartzite. The position of the gap, which is not shown on any of the published maps, is fixed by the following magnetic bearings:—Petermarra Hill, 184deg.; Mt. Augustus, 188deg.; Mt. Samuel, 215deg.; and Mt. Phillips, 220deg.

The quartzites are in places slickensided in many places along the dip of the beds, appearing as though there had been a certain amount of overthrusting which the section (Fig. 23) in the gap seems to verify.



SECTION ACROSS COORABOOKA GAP, LYONS RIVER.

Fig. 23.

Near the mouth of the gap and about 400 yards from the southern face of the range is a thin bed of quartzite conglomerate or breccia, five or six feet thick, resting upon the upturned edges of the sandy shales which underlie the flaggy quartzites. The bed which dips at an angle of about five degrees to the south is made up of

boulders and fragments of the massive quartzites of Coorabooka, embedded in a siliceous quartzitic matrix. This bed is merely a fragment of a talus or scree deposit such as characterises many of the ranges in the district.

The gravel and boulders which form the alluvium of Coorabooka Creek are in many places cemented into a breccia or conglomerate, sometimes several feet in thickness.

The Coorabooka Gap lies about 10 miles west of the "Remarkable Gorge" on the Frederick River* descended by F. Gregory on the 25th of June, 1861.† This explorer states, on that date his party on descending to the south across an open plain

> "Struck for a remarkable gorge in a granite range (the only one now between us and the Lyons), at which we arrived at sundown. On examining this singular gorge it was found to be an almost perpendicular cut through a narrow ridge nearly 300 feet in depth, the length of the pass not exceeding 200 yards, the plain on each side being nearly on the same level."

From Gregory's description it appears that farther to the east of Coorabooka granite country prevails, though I am inclined to think from what I was able to see during my journey that his "Remarkable Gorge" has been cut through quartzites of the Coorabooka type. Judging from the somewhat scanty topography indicated on the published maps,‡ the Coorabooka escarpment is virtually continuous along the Barlee Range, as far at any rate as the point at which it is pierced by the Hardey River near the big bend.

The route we followed from Coorabooka to the watershed of the Ashburton trended generally north 40 degrees east and carried us over a lofty tableland from which the descent was made by a somewhat awkward bridle track at an altitude of 540 feet above the morning's camp. Resting conformably upon the Coorabooka quartzites were a series of bedded lavas, which we crossed for about six miles; where the descent into the Ashburton valley was made the underlying quartzites dipped at an angle of about 20 degrees to the south.

The beds of tableland were arranged in the form of a synclinal trough of about eight miles in width; the axis of the trough trended generally north-west and south-east parallel to that of the Mount Augustus and Bangemall anticlines.

The divide between the two watersheds is formed of a bed of massive quartzite, the representative of that of Coorabooka, but not nearly so thick, and which formed a very prominent and bold escarpment extending for many miles in both directions.

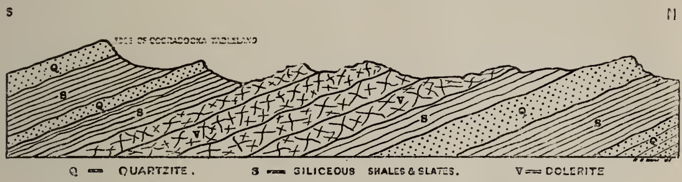
Descending into the valley of the Ashburton near the headwaters of what I take to be Secret Creek, the strata beneath the Coorabooka quartzite consist of sandstones and shales dipping south

* Lands Department, 300 chain Lithograph 78.

† Journal of Australian Explorations: by A. C. Gregory and F. T. Gregory. Brisbane, 1884, p. 67.

‡ Lands Department, 300 chain Lithographs 78 and 93.

at angles varying from 20 to 30 degrees. These beds occupy the country for some miles until their place is taken by a series of lavas which rise conformably from beneath them. These volcanic beds occur in great force, occupy a considerable area of country and are seen to rest upon a series of shales and sandstones as shown in Fig. 24.

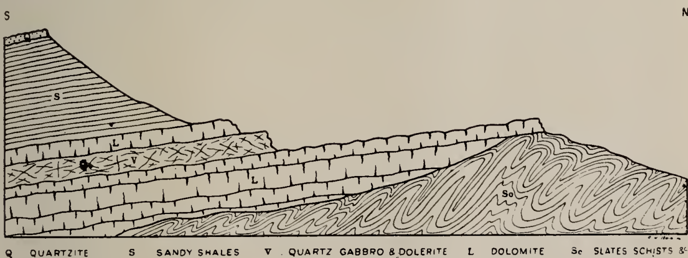


SECTION AT THE HEAD OF SOLDIERS SECRET CREEK
LENGTH 4 MILES.

Fig. 24.

Exigencies of travel rendered it necessary to continue the journey in the narrow cañon through which Soldier's Creek flowed. The course of the creek had been carried for considerable distances over the bedded lavas, which dipped at a relatively low angle to the southward. These lavas were underlaid by a considerable thickness of unfossiliferous flaggy limestone; beneath this were alternations of quartzites, sandstones, and shales; below the last-mentioned beds was a considerable thickness of limestone resting directly upon the bedded volcanic rocks. The whole series of strata dip at angles varying from 5 to 10 degrees to the south-east; a complete continuous section, 9 to 10 miles in length, may be seen in this portion of the creek.

About a mile west of the camp lay a very conspicuous isolated hill about 550 feet above the level of the creek in which the section shown in Fig. 25 is exposed.



SECTION NEAR THE MOUTH OF SOLDIERS SECRET CREEK

Fig. 25.

The section shows in descending order:—

Quartzite	25 feet
Sandy shales	400 feet
Dolomite	80 feet
Quartz dolerite or gabbro ..	120 feet
Flaggy dolomite	200 to 350 feet to base.

Some distance below the camp in the creek the quartz dolerite was seen resting conformably upon flaggy dolomites, 200 to 350 feet in thickness, with a few chert veins.

These rested with a violent unconformability upon the upturned edges of the slates, etc., which form the matrices of the auriferous deposits of Soldier's Secret, Mount Mortimer, Top Camp, etc. There was no conglomerate at the base of the sedimentary rocks which form the divide between the watershed of the Lyons and the Gascoyne.

This section is interesting in that it coincides with that seen at the Top Camp*, and described by Mr. H. P. Woodward in 1890. The Top Camp is about 25 miles south-eastward from the gorge on Soldier's Secret (Wandarry) Creek. Mr. Woodward thus describes the section†:—

Alluvial gold was first found on the Ashburton River, at the beginning of 1890, about 14 miles south of the tree marked 45 △, in a creek flowing down a gorge, about 200 feet deep, between steep cliffs of clay slate capped by almost horizontally bedded limestones. These clay-slates dip at a high angle to the north-east. They are intersected in places by small quartz reefs or leaders, in many cases ferruginous, but up to the present none of them have been proved to be rich in gold. The capping limestone (dolomite), the underlying shaley sandstone and ironstone beds are probably a northern and eastern extension of the Carboniferous and Devonian formations so largely developed on the Lyons and Gascoyne Rivers, though as yet no fossils have been found by which their age can be definitely fixed. The beds dip at an angle of 20 degrees south, resting unconformably upon the upturned edges of the clay slates (silurian?), and from their line of junction many strong springs break out. To the south these limestones form a large flat-topped range or tableland, and completely covering the clay slates, which are not exposed again, even in the gullies and the stream beds, although these are often of great depth. . . . . It is rather remarkable that there are no conglomerate beds in this district at the junction of these two formations; the limestone for the most part resting directly upon the upturned edges of the clay slates.

THE SOLDIER'S SECRET DIGGINGS.

(Geological Sketch Map, Plate I.)

At the time of my visit to the district there was no work of any description going on; hence there was little or nothing to be seen.

The situation of the diggings, sometimes known as Middle Camp, though more usually spoken of as Soldier's Secret, is about 14 miles south of the junction of the Ashburton with Wandarry Creek.‡

The auriferous deposits of Soldier's Secret are situated in the group of steep hills, about two miles to the north of the escarpment of the Bangemall Beds.

* Lands Department 300 chain Lithograph 93.
† Annual General Report for the Year 1890. Perth: By Authority, 1891, p. 20.
‡ Lands Department 300 chain Lithographs 92 and 93.

Mr. Woodward reports that up to the end of 1890 about 1,500 ounces had been obtained from this centre* and that the largest piece of gold found weighed about an ounce.

On the eastern bank of the creek near the old well, sunk by Messrs. Cook and Green, several very thick vertical quartz reefs outcrop. These have a general strike of 111 degrees and continue across country for considerable distances. The veins are enclosed in beds of slate which are virtually vertical and to the strike of which the reefs conform. In several instances these quartz reefs form the crests of prominent ridges and stand out in bold relief like walls of masonry.

The quartz, so far as I saw it, was invariably white and milky in appearance. It is doubtless from reefs of this kind that the gold in the gullies has been derived.

In one locality the slates were traversed by a vertical greenstone dyke on an average bearing of north 20 degrees east. The dyke also cuts through the very prominent vertical quartz reef which can be followed across country on a bearing of 108 degrees for a distance of about two miles. In all probability the dyke is connected with the volcanic plateau which occupies the divide between the Lyons and the Ashburton.

From the camp at Soldier's Secret the main track to the Ashburton River was followed, via Conical Hill and the Pinnacle.† The staple formation *en route* consisted entirely of slates, etc., dipping at a high angle to the north. The route lay through the Capricorn Range, which was discovered and named by F. Gregory on June 23rd, 1858.

Camp was pitched near a pool on the river at no very great distance from Mount Blair. The range in the vicinity of Mount Blair consists of beds of very ferruginous grits with thin shales (slates?) dipping at an angle of 30 degrees in a direction of north 30 degrees east. Some of the grits are in many places traversed by thin quartz veins.

The summit of Mount Blair rises by aneroid to a height of about 540 feet above the level of camp at the river. The strata at the top consist of a series of very ferruginous grits and thin shales, underlaid by thinly bedded and fine-grained ferruginous sandstones dipping north-east.

Leaving camp near Mount Blair exigencies of travel took us down the Ashburton River as far as Reserve 1119† where we camped at a fine pool in the river near Edygundy Creek. A cairn on the north side of the river on the extension of the Capricorn Range had been erected on a bed of quartzite with a strike of 130deg. and a dip to the south-west at 60 degrees. These beds dip in the opposite direction to those at Mount Blair. They form the other limb of a large fold which strikes generally north-west and south-east.

From Reserve 1119 we followed the main Ashburton road as far as the Dead Finish diggings and camped on the bank of the

* Loc. cit. † Lands Department 300 chain Lithograph 93.

river about four or five miles to the south. Camp was pitched just under a high hill upon which a cairn marked $\frac{C}{S}\wedge\!\!|$ had been erected.

The hill upon which this Trig. Station had been built attained a height of 700 feet above the bed of the Ashburton River as measured at a point due south of it. The hill itself is made up of micaceous sandstones dipping south and the ridge upon which the cairn has been erected forms part of a very acute synclinal trough, the longer axis of which has a general strike of 305 degrees. On the lower slopes of the hill, which form the river bank, there is some evidence of overthrusting, in which a somewhat calcareous slatey band has been brecciated and a rude schistosity induced. The thrust plane dips at a gentle angle in a northerly direction. The hills being devoid of timber and grass the geological structure of the range can be readily and distinctly made out.

A traverse was made to the southward of the camp for some miles but sections showed nothing but a great thickness of highly inclined sedimentary rocks all of which form part of one and the same geological series.

THE DEAD FINISH DIGGINGS.

(Geological Sketch Map, Plate I.)

The Dead Finish Diggings are situated on the north side of the Ashburton River about five miles north of the Survey Station 35 $\triangle$* and about the same distance north of Cairn $\frac{C}{S}\wedge\!\!|$. Mr. Woodward reports† that at the end of 1890 it was estimated that about 1,000 ozs. of alluvial gold had been obtained from this centre and that whilst the gold was mostly shotty in character the largest piece recorded at that time weighed about 8 ounces. There unfortunately have been no separate records kept of the gold obtained from this individual centre.

There are several abandoned workings in the vicinity but no work was going on at the time of my visit, and there was very little to be seen of anything.

An old lease, one of the pegs of which was marked G.M.L. 11, was made up of vertical slates, the general strike of which was east and west and was traversed by a cross reef striking north 45 degrees east. The reef had been worked by means of two shafts, neither of which was accessible. A gully below the two shafts had been extensively worked for alluvial gold in past years.

A Government well had been sunk to a depth of 90 feet through slate at Dead Finish, but unfortunately the water proved to be salt and totally unfit for domestic use.

The hills at Dead Finish were composed of vertical beds of quartzites striking about 122 degrees. These quartzites are in many cases traversed by quartz reefs parallel to the strike of the beds, which are disposed in a series of more or less acute folds. The quartz reefs occur on the flanks of the arches and may possibly represent the legs of saddle reefs now modified by denudation.

* Lands Department 300 chain Lithograph 93. † Loc. cit. 21.

From Dead Finish we followed down the valley of the Ashburton River and camped at the Gorge Police Camp, near the tree marked 31△, on the opposite bank of the river to Reserve 1115.* The strata exposed in the vicinity of the camp are very ferruginous sandstones of the Mount Blair type.

To the southwards in the direction of the hilly country the sedimentary beds are exposed in great force; at one spot there is a considerable thickness of massive conglomerate, dipping to the north-east at an angle of about 25 degrees. The conglomerate rests upon an unmeasured thickness of sandstone and quartzite, and is overlaid by a very ferruginous sandstone of the type which characterises Mount Blair. The pebbles in the conglomerate consist principally of quartz, quartzite, jasper, etc. The conglomerate is traversed by very many thin quartz veins. In one portion of the conglomerate a quartz vein is seen to intersect the component pebbles. The sedimentary rocks are traversed by a dyke of a sheared igneous rock [7618] a porphyroid.

In the vicinity of the gorge some very nice gold nuggets were said to have been found, but at the date of my visit there was no person at work anywhere in the district.

THE MOUNT MORTIMER DIGGINGS.

(Geological Sketch Map, Plate I.)

From the Police Camp exigencies of travel took us to the Mount Mortimer diggings, which are situated some distance to the south-east of Mount Dawson, or Mount Mortimer as it is generally known in the district.*

In the more immediate vicinity of the diggings, which lie about three miles to the north of the escarpment of the Bangemall Beds, the country rock consisted of highly inclined sandstones and grits, occasionally faulted and traversed here and there by quartz veins and leaders of very varying dimensions.

One of the larger veins crosses the creek from which a large quantity of alluvial gold has been obtained, but although parts of the reef proved very rich it petered out at a comparatively shallow depth.

At the summit of a hill upon what was known as Brownrigg's Claim was a very pronounced outcrop of quartz, which contained a few kernels of galena [7723]. An assay of a sample made in the Survey Laboratory yielded 1dwt. 2grs. of gold and 18ozs. 7dwts. 6grs. of silver per ton, together with 59.60 per cent. of lead. The outcrop of the vein was not very long and I failed to discover any lead ore in it other than the sample I took for assay. Near the foot of the hill and some distance from the summit, a tunnel 80 feet in length had been put in in a direction of north 20 degrees east, with the object of cutting the lead-bearing quartz vein at some distance vertically below the outcrop. It passed through nothing but

* Lands Department 300 chain Lithograph 93.

almost vertical beds of sandy shale; the impression left on my mind was that the tunnel had not been carried far enough to intersect the extension of the vein, though to definitely settle this point a much more accurate survey than I felt justified under the circumstances in carrying out would be required.

According to Mr. Woodward's observations made in the year 1890* very coarse gold was obtained from many of the gullies, and the largest piece weighed 56 ounces. The alluvial gold was reported to have been associated with ironstone to such an extent that the lumps had often to be crushed in order to separate the gold.

No separate record appears to have been kept of the gold yield of the Mount Mortimer centre.

While at Mount Mortimer I made a few traverses southwards as far as the tableland dividing the Henry and the Ashburton Rivers, and which forms the north-western extension of that we crossed in journeying from Bangemall to Mount Blair.

The unconformity separating the auriferous series from the Bangemall Beds was well seen in the vicinity of the gorge where Irregully Creek emerges from the tableland. The dolomite at the base of the series rests upon a thin bed of conglomerate two to three feet thick, which seems to indicate the approach to shore conditions.

Some little distance below the gorge the auriferous series is well exposed in a section along the bank of the creek, and the beds are traversed by a fault shown in Fig. 26.

FAULT IN AURIFEROUS SERIES, IRREGULLY CREEK, ASHBURTON RIVER.
Fig. 26.

* Loc. cit., p. 21.

Opportunity was taken to make a traverse up Irregully Creek with the object of examining the beds lying above the thin basal conglomerate. For some distance above the mouth of the gorge it is found that the beds lying more immediately above the conglomerate

FLAGGY LIMESTONES AND CONGLOMERATE BELOW THE DOLOMITE, IRREGULLY CREEK, ASHBURTON RIVER.
Fig. 27.

consist of flaggy dolomites dipping at angles of 10 degrees to the south. One section some distance up the creek shows a little minor faulting and contortion in the dolomites.

Near the top of the limestone series, which is about 300 to 400 feet in thickness is a bed of quartz-gabbro or dolerite [7728] of the type exposed in Soldier's Secret Creek. This is conformably covered by a series of thin flaggy limestones upon which shales, fine sandstones, and quartzites rest. These latter beds, as seen from a commanding eminence of quartzite 850 feet above the level of the mouth of the gorge, evidently occupy a very considerable area of country in an east, west, and southerly direction. The whole section above the gorge is identical with that seen in Soldier's Secret Creek. The escarpment of the Bangemall Beds may be seen following the south bank of Irregully Creek for a considerable distance to the north-east.

From Mount Mortimer Diggings I returned to the Ashburton River and followed the main road as far as Simpson's Crossing, near Reserve 1113.* In the river at the crossing vertical slates, trending east and west, are exposed. On the western bank of the river a little distance to the south of Reserve 1112 is an escarpment

* Lands Department 300 chain Lithograph 93.

formed of what appears, when viewed from a distance, to be beds of the Bangemall Series.

Close to Metawandy Creek and bearing from Mount De Courcey* 185 degrees is a deposit which had been worked in a more or less desultory fashion. The deposit itself outcrops near the highest summit of a long somewhat narrow ridge not far from the creek. There is no defined lode exposed, the deposit (Fig. 28) consisting of a fairly thick bed of country rock which has been per-

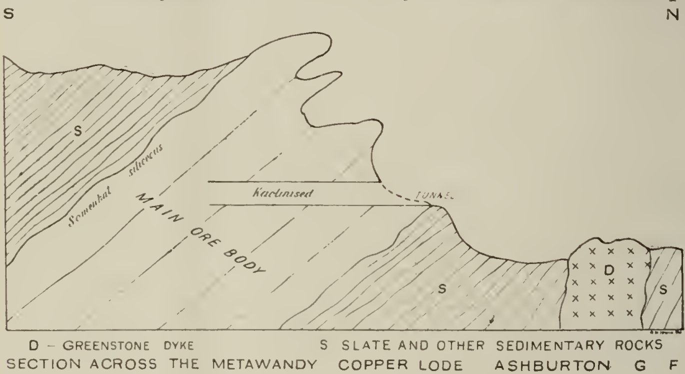


Fig. 28.

meated by copper-bearing solutions in certain portions. The northern face of the escarpment (the outcrop of the lode) makes an unusually conspicuous feature in the landscape, and rises to a height of about 30 to 40 feet from its base at the mouth of the tunnel. In certain portions of the escarpment the stains of the green carbonate of copper can be seen even at a distance. At one spot, where a fairly well-defined quartz vein, containing green carbonate of copper along its fractures, a tunnel has been driven into the face of the hill for a distance of about 55 feet in a southerly direction. Nothing of any value, however, was exposed, though at the face of the tunnel is a little green carbonate of copper and a few cubes of iron pyrites. The rock exposed in the tunnel is very much weathered and kaolinised, rendering it almost impossible to indicate its original condition and nature. Along the hanging wall the ore body is somewhat siliceous. From such observations as it was possible for me to make on the few exposures available, the impression left on my mind was that the deposit was nothing more than a concentrating proposition, though of too low a grade to be commercially profitable.

Some little distance from the Metawandy lode another small copper deposit had been opened up and a fair amount of prospecting done upon it. This deposit, work upon which had ceased a long time prior to my visit, consisted of a vertical quartz vein of no great

* Lands Department 300 chain Lithograph 93.

thickness. The outcrop could be followed along the surface for a considerable distance in a direction of north 65 degrees east; in one portion of its course the vein was intersected at right angles by a vertical greenstone dyke, ten feet in thickness. The copper ore consisted of "tile ore," malachite, and copper sulphide, the latter occurring in small bunches. The deposit itself is a fissure vein occurring at right angles to the general strike of the country, which in this neighbourhood dips at a high angle in a direction of south 60 degrees west.

From our camp at Coorara Claypan, Reserve 30, some distance below Hardey Junction Station, an opportunity was taken to examine the range of which Mount Edith* formed the most conspicuous summit.

In the vicinity of the camp at Coorara the strata exposed consist of almost vertical sandstones, etc., of the Mount Blair type of which there is but little doubt that they form part.

Mount Edith lay some little distance to the north of the camp, the strata between the camp and the base consisted of sandstones, etc., together with fine micaceous sedimentary schists trending generally east and west and standing practically up on end. These vertical strata are overlaid by beds of pure dolomite [7730] seamed in places with quartz veins, some of which are ferruginous. It is not by any means as yet quite clear whether these dolomites are not the equivalents of those which form the tableland drained by Irregully Creek, etc.; much more detailed investigation in the field, however, will be required before this can be definitely decided.

Mount Edith is made up of a laminated iron-bearing quartzite which dips south-east at an angle of about 25deg. and strikes generally north-west and south-east, which is the trend of the range of which it forms a part.

In one portion of the range and not far from the summit was a conspicuous band of crystalline hematite [7729]. An analysis of it at the hands of Mr. E. S. Simpson gave the following results:—

$Si\,O_2$	1·70
$Ti\,O_2$	·06
$C\,O_2$	*nil*
$P_2\,O_5$	·06
$S\,O_3$	·05
$H_2\,O$ (combined)	·57
$Ca\,O$	·12
$Mg\,O$	·14
$Mn\,O$	·03
$Fe\,O$	·90
$Fe_2\,O_3$	96·75
$Al_2\,O_3$	·28
$H_2\,O$ (hygr.)	·06
	100·72
Sp. Gr.	4·93

* Lands Department 300 chain Lithograph 93.

This ore, containing as it does 68.42 per cent. of metallic iron, phosphorus .026 per cent., and sulphur 0.20 per cent., is a very rich hematite ore. The complete analysis shows it to be low in silica and with but a small percentage of titanium.

Leaving Coorara Claypan we followed the main road down the river and camped at a spot midway between the mouth of Duck Creek and Cobbler's Pool, not far from Reserve 1236.* Granite proved to be the prevailing rock in the river at this spot, though its relation to the beds of Mount Hubert could not be ascertained in the short time at my disposal.

From the mouth of Duck Creek the main road was followed to what is known as the White Rocks Pool, Reserve 1235.*

The greater part of the route lay on granite and its decomposition products; at a point bearing to Black Hill* 55 degrees, vertical micaceous slates make their appearance and the junction between the two can be seen.

Micaceous schist traversed by a large vertical quartz reef forms the western bank of the river at the pool. The quartz reef is 20 feet in thickness in its widest part and has a general strike of 120 degrees.

From the White Rocks to our next camp on the river our route lay through some rough hills in which limestones, sandstone, and quartzite were exposed.

The next day's travelling carried us over nothing but granite to Nanutarra Station, at which point our route crossed the Ashburton River by the road to Uaroo Station, in the vicinity of which were the lead and copper mines.

For some little distance after crossing the river a small patch of micaceous schist is exposed, which ultimately gives place to granite, which, where it has been exposed in a station well alongside the road is very coarse-grained, containing many very large porphyritic crystals of felspar.

From our night halt at this well we travelled to Uaroo Station on Rous Creek, and from thence about four miles to the northward to a convenient camping place at a well on the western bank of the creek.

From this camp a more or less detailed examination of all the mines in the vicinity was made.

The work occupied me from the 12th of September until the 11th of October, 1907.

THE UAROO LEAD AND COPPER MINING CENTRE.

(With a Geological Map, Plate III.)

The mining centre of Uaroo is situated 80 miles from Onslow, upon Rous Creek, which forms one of the numerous branches of the Ashburton River. The mail coach road from Onslow to Hancock's Station, on the Upper Ashburton, passes through Uaroo.

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* Lands Department 300 chain Lithograph 96.

The mining centre lies just to the west of the junction of an area of granite, which occupies such an extensive tract of country in the district.

The district of which Uaroo is the centre is formed of a series of lofty precipitous serrated ridges trending generally north-west and south-east. The general trend of these ridges has been determined by the outcrop of the siliceous rocks and veins of which they are everywhere made up. The ridges, as may be seen by an inspection of the Geological Map, are breached almost at right angles by several important watercourses, and others of smaller dimensions occupy the longitudinal ravines between the different ridges.

As the whole of the ore-bearing area was a complete blank upon any of the existing maps, operations had to be commenced by preparing a geological sketch map embracing what is, as at present understood, the productive area. The work was carried out by a modification of the planetable and stadia method, which readily lends itself to the requirements of the economic geologist. The ground covered by this work comprises a belt of country about four miles in length and about three miles in breadth, which is depicted upon the Geological Sketch Map (Plate III.).

Detailed surveys were made of two of the ore deposits, the Pedan Copper Lode and the Uaroo Silver Lead Lode, which seemed to be instructive examples of two types of lodes as developed on the field, in the hope that they might in some measure furnish a guide to the general behaviour of veins of this type in the locality.

The result of these surveys has been embodied upon plans on the scale of 10 chains per inch accompanying this report, and forming Plates IV. and V.

Six mineral leases were in force at Uaroo during one period of its history but at the present time there are only two existing.

The Acting Warden of the Ashburton Goldfield, Mr. A. Phelps, in his annual report for the year 1901 makes the following references to the discovery of the lodes of lead and copper*:—

It affords me much pleasure to report the discovery of mineral lodes by Fitzgerald's party and Mr. T. H. Smith at Uaroo, in the Lyndon division. Uaroo is distant about 84 miles from the Port of Onslow, and it is here that Fitzgerald's party found the silver-lead mine known as "The Rainbow." . . . . The lode is an argentiferous lead ore; its strike is north and south, and outcrops on the surface for some distance, and has a slight underlay to the east. A tunnel has been put through the hill on the course of the ore body, exposing large quantities of sulphide and carbonate ore.

The ore body was also struck in a shaft 50 feet on the hanging wall side of the lode; the lode was then driven on to the south a distance of 40 feet. The ore obtained in this drive is of good quality; it averages over 3 feet wide . . . . Samples I obtained on the surface, and forwarded to the Department for assay, gave the following return:— Silver, 29.11ozs.; lead, 69.02 per cent.; copper 29.88; gold, 19grs. per ton. . . . . The copper lodes discovered by Mr. T. H. Smith are

* Report of the Department of Mines for the Year 1901. Perth: By Authority, 1902, p. 49.

situated about four miles north of the "Rainbow" mine. The copper obtained from the leases applied for in the vicinity is of high percentage and easily treated. Very little development work has been done to prove them, but from surface prospects they are very favourable. . . . .

The Secretary for Mines in the annual report of the Department of Mines for 1902 remarks*:—

Almost all mining operations at Uaroo, Red Hill, and Mt. Stuart for copper have ceased. A parcel of 300 tons of lead ore is now being carried from the Rainbow mine to Onslow. . . . .

The advance in the market value of lead and copper led to the re-opening of the deposits in the district and the discovery of others which have been more or less perfunctorily worked.

In the year 1901 Mr. S. Göczel, a former officer of the Geological staff, was commissioned by the Minister for Mines to visit and report; a *resumé* of this gentleman's researches was given in the annual report for the year 1901.‡ As Mr. Göczel's observations do not appear to have been printed *in extenso* officially, I have deemed it expedient to include them in this report:—

THE ORE OCCURRENCES ON THE ASHBURTON RIVER.

By Mr. S. Göczel (dated November, 1901).

In following the course of the Ashburton River upwards from its entrance into the sea near Onslow, during the first 50 miles a plain is traversed, the surface of which discloses only fluviatile-alluvium and a few sand-dunes. After passing that distance archaean gneiss, presenting occasionally granitic texture, and strata of crystalline schists are met with. The latter are crumpled and eroded and form the most prominent mountains and hill ranges. The crystalline schists contain the ore deposits. A look out from a mountain top discloses the presence of topographical features produced by the crystalline schists for miles and miles in a northerly, southerly, and easterly direction, and inquiries made from settlers, travellers, and prospectors justify my conclusion, that the lately reported ore-deposits are situated within an ore district of more or less uniform geological character, and that the extent of that ore district attains gigantic dimensions. My own limited observation admits a width of over 50 miles, and answers to my inquiries confirm the presence of crystalline schists and of ore deposits for a longitudinal north-south extent of over 150 miles. The reported ore deposits are situated north of and near Uaroo Station. A series of schistose strata form here a hill range; on the eastern decline of that hill range the reported discoveries occur. The alternating strata consist of mica schists, quartzites, conglomerates, ferruginous-mica schists, in which magnetite and specular-iron ore are very prominent, and also of dioritic schists.

The strata have a west of northerly course, and a steep easterly underlay.

The deposits are lenticular ore bodies enclosed within the strata. They follow an almost continuous quartzite seam for over six miles. Transverse fissures, bends, and dislocations appear to be conditions for increased richness. Pale clay slates from a few inches to several feet in width, accompany the ore occurrences, and follow the ore bodies on occa-

* Report of the Department of Mines for the Year 1902. Perth: By Authority, 1903, p. 32.

† Annual Progress Report of the Geological Survey for the Year 1901. Perth: By Authority, 1902, pp. 9-11.

sional short transverse courses through the stratified country. The line of ore deposits can be considered as a series of bedded lodes, showing the characteristics of the seam as well as those of the true fissure. The southern portions of that line of ore deposits has, besides copper ores, argentiferous lead occurences, and is occupied by a group of leases which are termed the Rainbow group, whereas the northern or Long Tom group of leases covers copper ore outcrops.

As yet mining operations have only been commenced on the Rainbow Reward Lease. The ore body worked appears to be situated on a lode-cross formed by a cupriferous quartzite seam running 25 degrees west of north and a transverse fissure with a course of 20 degrees east of north. This transverse fissure dislocates the quartzite seam for some distance, and introduces the argentiferous lead ores into the lode-cross. There are indications of the presence of several such cross fissures; the principal ones are galena, carbonate of lead, and green and blue carbonate of copper. About 70 tons of high grade ore are bagged on the surface. A shaft at present being sunk has attained a depth of 40 feet, and will cut the ore body at a depth of 50 feet.

No work has yet been commenced on any of the Long Tom group of leases. The outcropping ore bodies follow a quartzite seam running from 15 to 35 degrees west of north. The outcropping ores are carbonates of copper, red oxide of copper, bornite, chalcopyrite, and chalcosite. A considerable silver yield in samples taken from the outcrops indicates the probable occurrence of argentiferous grey ore. The outcropping ore bodies show widths of from a few inches to three feet. The ore is clean and high grade.

Similar ore deposits are known to exist in many places of the district, and many more are still awaiting discovery. There can be hardly a doubt that the country to the north and south of the Ashburton River will, sooner or later, offer many opportunities for profitable mining enterprise. Judging from analogous occurrences and features in other parts of the globe, antimony, cobalt, and nickel, and even quicksilver and tin ores, may possibly be found within the district.

The difficulties facing the miner at the present time are enormous; distance to the coast, want of cheap fuel and mining timber, and a tropical climate cast a spell of discouragement. On the other hand, there is the possibility that it may be worth while to face and overcome these difficulties.

The discovery and disclosure of a further number of ore deposits in the indicated district is bound to happen within the near future, and the number, size, and richness of such ore deposits may warrant the construction of a mining tramway to the coast, and also a systematic search for productive coal measures in the vicinity.

The present season is very unfavourable for prospecting. The great summer heat and a scarcity of grass make it difficult to move about. The months from April to November are considered the favourable season for prospectors.

Should mining operations in the indicated district become numerous, an indiscriminate cutting down of the trees along the water courses would rob the latter of their natural protection. Waterholes now considered permanent would become filled by drift sand. By such proceeding a great portion of the value of the country for pastoral purposes would become destroyed. To avoid irreparable mistakes in that direction, a regulation for procuring a mining timber and firewood supply from the limited resources of the district should be devised, with a view of tiding over the initiatory stages of mining in that district.

The water supply of this district is good, and within the crystalline schists water is usually struck at depths of about 30 to 100 feet.

Before concluding, I wish once more to point out that although this district impresses me very favourably, judicious discrimination should

be exercised, both on the part of the prospectors and the capitalist, before embarking into mining enterprise in the north-west.

Geological Texture of the Ashburton Ore District.

Extensive strata-complexes of crystalline schists in conjunction with a granitic-gneiss substratum are the principal geological features of the Ashburton ore district.

Those features form a zone, the longitudinal extent of which trends in a north-south direction.

Granitic gneiss is exposed by erosion in large areas; it presents cupola-form texture along axial lines—the crests of anticlinal folds.

On the flanks of each of those gneiss areas, strongly folded strata of crystalline schists—presenting prominently anticlines and synclines—form the most conspicuous mountains and hill ranges of the district.

The crystalline schists occupy basin or bight form depressions within the gneissic substratum.

In the adjoining map* some of the granitic gneiss outcrops and crystalline schist complexes are indicated by respective colouring, and a cross section between Uaroo and Mt. Alexander will serve to illustrate relative situations and texture.†

The crystalline schists overlay the gneiss seemingly conformably, but as only their relative highest strata appear in the overlapping wings, it must be concluded that the superposition is unconformable. About two and a half miles south of Uaroo Station a gorge traverses a fold in which lower strata of the crystalline schists, several thousand feet in width, form an anticline; those strata take no part in the wing-forming synclinal fold.†

The line of division between the wing-forming upper strata and the lower series coincides more or less with the line of ore outcrops near Uaroo Station. A conglomerate seam several feet in width appears persistently near this supposed line, and contains rounded gneiss and quartzite pebbles.

The lower series of the crystalline schists consist chiefly of mica-schists alternating with siliceous schists and small quartzite seams; the upper ones of mica-schists, quartzites, of ferruginous schists with local developments into ironstone seams (hematite, magnetite, specularite, limonite, ilmenite), chloritic-hornblende-schists, and calcareous schists.

The ore deposits near Uaroo occur within the crystalline schists, and follow more or less a quartzite seam for over six miles; the latter is in many places dislocated by transverse fissures. The strata have a west of northerly course and a steep easterly underlay. Series of lenticular outcrops of copper ores occur sometimes to the east and sometimes to the west of the quartzite seam.

The ore bodies occasionally adjoin and merge into the quartzite; in other instances they occur at some distance from the quartzite and within the mica-schists. Changes from the eastern or hanging wall country into the western or footwall country of the quartzite seam are apparently effected by transverse fissures.

Figures B and C show such changes as they occur respectively in the Rainbow, Comet, and Long Tom leases.‡

From such occurrences it can safely be concluded that the ore deposition took place in fissures, which fissures, on account of the stratified character of the country, follow mostly the lines of stratification. Pale clay slates from a few inches to about two feet in width accompany the ore occurrences, and indicate rock movement along the lode planes.

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*Not reproduced.

† *Vide* Diagram A. Section from Uaroo Station to Mount Alexander. Annual Report, Geological Survey, 1901. Perth: By Authority, 1902, page 10.

‡ Diagram B.—Plan of the Ore Deposit in the Rainbow Mine, near Uaroo. Diagram C.—Plan of the Ore Deposit in the Long Tom Mine, near Uaroo. Annual Report, Geological Survey, 1901. Perth: By Authority, 1902, page 10.

From the nature of the ore outcrops it can justly be expected that the ore bodies in a downward direction will appear as series of ore-lenses, dipping diagonally between the strike and the underlay of the strata.

The ore showing in some of the outcrops is clean and high grade. In some instances a considerable silver yield has been ascertained, the latter is associated with the sulphides, and therefore likely to increase in depth.

Carbonate of copper (malachite) and red oxide of copper (cuprite) form the bulk of the secondary ores, whereas bornite, copper-glance (chalcosite), and copper pyrites represent the sulphides. Sulphides as well as secondary ores crop out on the surface. Outcropping ore shoots show no gossan cappings.

In the Rainbow Lease argentiferous galena and carbonate of lead (cerussite) occur besides copper ores.

Other Ore Finds.—Ore samples similar to those found near Uaroo have been submitted to my inspection by different persons; those samples were obtained from the vicinity of the following localities, viz., Red Hill, Mt. Stuart, Mt. Alexander, and The Peak. A glance at the map and the consideration of the distances which separate those ore finds from one another point to a gigantic extent of the Ashburton ore District.

Hints to Prospectors.—Analogous geological texture and similar petrological constitution in well known and exploited ore districts of Europe (Northern Hungary, Bohemia, Saxony) justify me in pointing out *possible and probable occurrences of valuable ore deposits*, differing in character from the above discussed, within the Ashburton ore district.

A.—*Within Areas of Archaean Gneiss.*

Quartz lodes with antimony and gold. Lodes containing lead, silver, and partly copper ores. Such lodes would present gossan outcrops.

B.—*Within the Crystalline Schists.*

Besides copper ore deposits similar to those at Uaroo, other lodes with gossan outcrops will be found to occur. Such outcrops deserve, therefore, the attention of prospectors. To avoid mistakes in this matter, I may point out that gossan-ironstone presents usually a spongy or honeycombed texture, and consists chiefly of limonite, whereas the ferruginous and ironstone seams of the district are as a dense texture, and contain chiefly hematite, magnetite, titaniferous specularite, and ilmenite.

Of the occurrences of siderite lodes I have almost certain proof, their outcrops appear as manganiferous ironstone, the latter occasionally pseudomorphous after siderite (obtuse-angular rhombohedrons). Such lodes, although their outcrops may contain no valuable metal, may still enclose lenses of rich copper, silver, and quicksilver ores.

Some of the copper lodes will probably contain grey ores, and thereby become productive of silver or quicksilver, or of both. Intrusive gabbro within the schists, if encountered, should suggest a search for cobalt and nickel ore deposits.

C.—*Within both the Archaean Gneiss and Crystalline Schists.*

Under access of some granitic or porphyritic eruptive rock, tin lodes, or stockworks, may occur, and in adjacent gullies and creeks, stream tin.

Search for productive Coal Measures.—As there is a great likelihood that discoveries and developments of ore deposits within the Ashburton District will necessitate a large supply of fuel, I may just as

well mention that the best solution of this problem would lie in the finding of coal in the vicinity.

If my memory serves me rightly, there exists palæontological proof that extensive strata-complexes along the north-west coast are of carboniferous age; if so, a closer geological examination supplemented by trial borings may possibly effect the discovery of productive coal measures.

GENERAL GEOLOGY.

The whole of the ore-bearing area of Uaroo is occupied by one geological formation, which consists of a continuous series of sedimentary rocks, some bands in which having evidently undergone more or less mechanical deformation.

The beds consist of quartzites, phyllites, and conglomerates, which have an average strike of north-west and south-east and a steep dip to the north-east. As may be seen by an inspection of the Geological Sketch Map there is distinct evidence of folding, for at a spot about 15 chains due west of the south-east angle of the Long Tom Mineral Lease 8 the beds dip at angles between 50 and 60 degrees to the south-west. This, however, is the only evidence of an anticlinal fold observed within the limits of the area described.

A very marked feature in the structure of Uaroo is the prominent band of laminated quartz, LQR on the map, which traverses the western portion of the area, and upon which the westernmost angle of Mineral Lease 25, Star of the West, is situated. This band rises in the form of a rough serrated ridge and can be traced across country for a considerable distance, although it was not deemed expedient to devote any time to mapping in its whole extent. On the Pedan South Lease, M.L. 61, the strata are traversed by a greenstone dyke about 15 chains in length. This is the only igneous rock noticed in association with the ore deposits.

The strata are traversed by several faults, but of what magnitude there is no evidence. They are, however, of later date than the mineralisation of the district, for in all cases do the faults affect the lodes and barren quartz veins.

The relation which these sedimentary rocks bear to the granite lying to the eastward and which underlies the flats is by no means clear, but the impression left on the mind after a careful investigation of the district is that the junction between the two is marked by a line of fault.

There is no evidence at present available to show the age of the strata; they however agree in all their essential lithological characters with the auriferous series of Mount Mortimer, etc., to which reference has been made in the earlier pages of this report.

After the mineralisation of the area the district seems to have been subjected to considerable earth stresses, for many of the large massive quartz reefs have been rendered more or less fissile.

Many of the conglomerates are traversed by both vertical and horizontal joints, many of which cut clean through the component pebbles.

To the west of the Dark Horse lode is a mass of quartzite and conglomerate, about 900 feet in thickness, which dips to the eastward at angles of from 60 to 70 degrees. From beneath these rise about 500 feet of an iron-bearing quartzite which forms a very prominent ridge trending along the field. This quartzite is traversed by a well-marked brecciated quartz and ironstone lode about 30 chains in length and which is conformable to the dip and strike of the strata. Underlying this is a considerable thickness of flaggy micaceous quartzite. The conglomerates in the vicinity of the Uaroo silver lead mine give evidence of having been subject to a considerable amount of shearing, etc., and now appear [7738] as impure sheared quartz conglomerates.

Many of the beds have been subjected to a secondary silification to such an extent that in some cases it is a difficult matter in hand specimens to differentiate between reef quartz and quartzite.

The micaceous beds are represented by phyllites, some bands in which are garnetiferous [7733] and others hematite-bearing [7732]; in some cases these form the matrices of the copper lodes. Full descriptions of these are given in Mr. Thomson's Petrological Notes.

THE ORE DEPOSITS AND MINES.

The ore deposits of Uaroo are, as may be seen by the map, quartz veins which traverse the whole length of the field.

The position of all the veins has been laid down upon the geological map of Uaroo with such a degree of accuracy as the scale of the field plan and the necessities of the work permitted. No quartz vein, which is obvious to any one making a fair and reasonable inspection of the surface, has been overlooked or omitted from the map. These quartz reefs exhibit, when viewed on the whole, a general parallelism to the strike of the main structural features of the district.

A careful examination of all the veins showed that they can be divided into two totally different types which in the field may be sharply differentiated from each other, though the distinction between them can hardly find adequate expression in words.

For convenience of description the mines and workings are described in geographical sequence, commencing at the north-westernmost end of the field.

Pedan, M.L. 60.—The 48-acres lease now known as the Pedan, comprises in part the southern portion of the old North Sunset lease, M.L. 31, and the Star of the West lease, M.L. 25, both of which were applied for in the year 1901. In its present form the Pedan was applied for by Mr. F. L. Finch in June, 1907.

The only work of any importance done upon the mine consists in the deepening of an old shaft by which mining operations had been carried out by the earlier holders of the ground.

A large plan on the scale of 100 feet to the inch was prepared of the Pedan copper lode and has been reproduced on Plate IV., thus rendering the description somewhat more intelligible.

The most pronounced feature on the property is the very large white quartz reef which occupies the highest portion of the ground, directly overlooking the main shaft. This quartz reef reaches a maximum thickness of about 3½ chains; both to the north and south the reef gradually tapers out until it is represented by a film of quartz no thicker than a sheet of paper. This large quartz reef is, so far as can be seen on the surface, entirely devoid of any mineral.

The only mining operations carried out on the main lode consist of the sinking of a vertical shaft about 100 feet in depth and a certain amount of driving as well as two open works adjoining the main shaft.

As may be seen by an inspection of the plan of the lode, Plate IV., what is known as the main lode has a length of about 500 feet and traverses almost vertical beds of sandstone and quartzite.

A second copper-bearing quartz vein outcrops at the main shaft and is exposed in the southernmost open work, situated about 10 to 14 feet from the main shaft. The quartz reef varies from one to two feet in thickness and contains more or less green carbonate of copper. The lode as seen in the open cut underlies to the eastward at an angle of about 75 degrees and passed into the south-west angle of the shaft at about six or seven feet from the surface. This lode can be followed, more or less interruptedly, up the slope of the hill to the north for a distance of about 250 feet, where it appears to intersect the large quartz reef which forms the summit of the high ground to the north of the main shaft. It is, however, so far as can be seen on the surface, very thin and its copper content is very low indeed. To the southward this lode is cut off by the well-marked fault, indicated on the plan as trending generally north-west and south-east. It is by no means improbable, however, that its southern extension is represented by the well-marked copper-bearing quartz reef which outcrops about 160 feet to the south-west and on the other side of the fault.

The westernmost opencut is that upon which most of the work has been done and is the one in which the main copper lode is exposed. At the most westerly end of the opencut the lode, which is about six feet thick at the surface, has been followed down to a depth of about 12 feet, at which depth its thickness proved to be about four feet. This lode can be followed along the surface for a distance of 250 feet on an average bearing of 285 degrees. The lode is evidently along a line of fault for, as may be seen on the plan, two sandstone beds on either side have a horizontal displacement of about 20 feet. For a distance of about 130 feet along the outcrop the lode is very thin, and it does not appear to be rich in copper; in fact in many places it is virtually barren.

PE

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BULLETIN No. 33 PLATE IV.

The Hon. H. Gregory M.L.A.
Minister for Mines.

PLAN OF
THE PEDAN COPPER LODE

UAROO

ASHBURTON G. F.

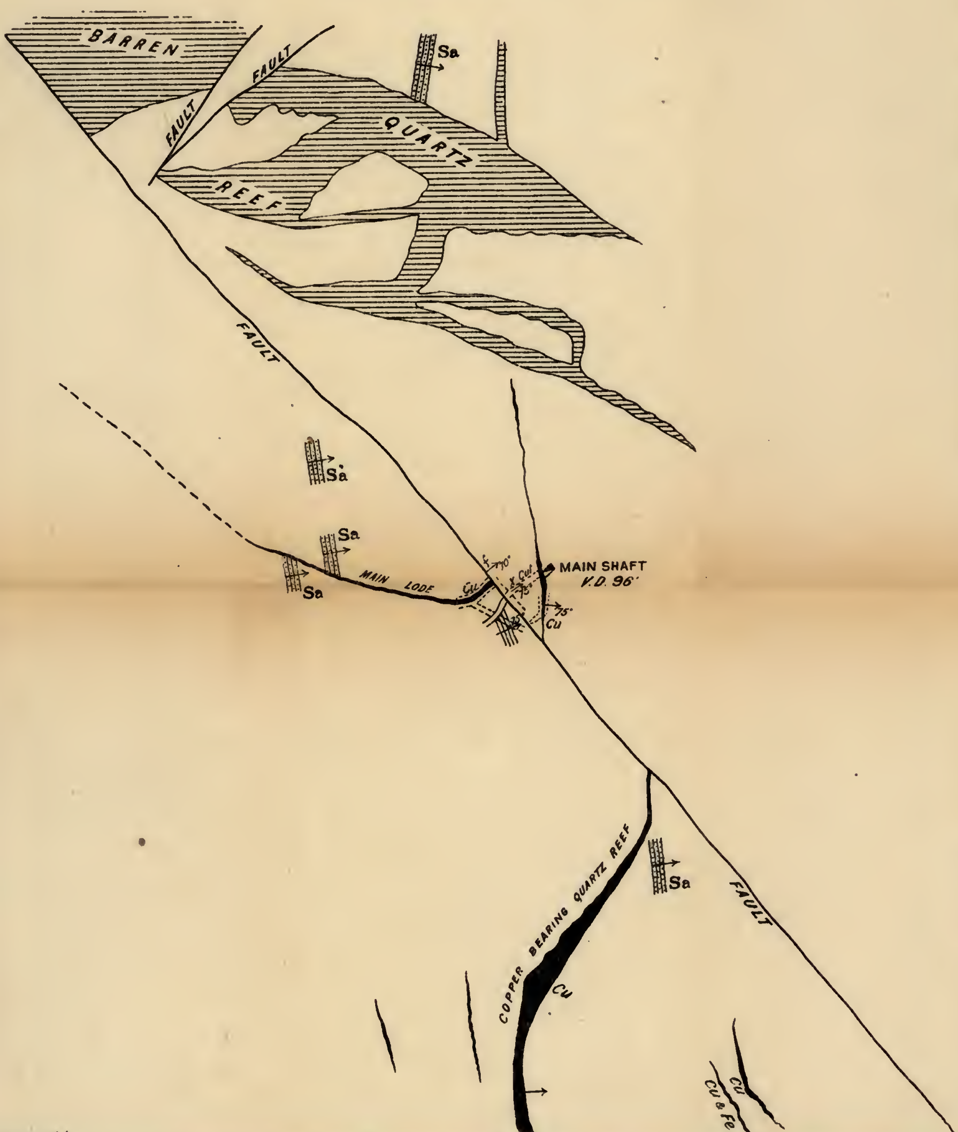
BY

A. Gibb Maitland.

GOVERNMENT GEOLOGIST.

0 100′ 200′ 300′

Scale of Feet



R.H. Irwin del:

H J Pether, Government Lithographer, Perth, W A

In the opencut 14 feet in depth the lode swings round to a bearing of about 52 degrees. and at 30 feet from the western end it is abruptly cut off by a fault with a hade to the north-east of 75 degrees. This fault is met with in the western crosscut, which has been put in at 30 feet from the centre of the main shaft at a depth of 30 feet from the surface. After meeting the lode it was followed south-westward for a distance of about 24 feet.

With the object of proving the lode at a depth, the main shaft was deepened to 96 feet, and I am informed by Mr. Finch, the local representative of the syndicate, that the copper lode was met with at a depth of 85 feet from the surface and that it proved to be five feet in width, mostly in good ore, averaging about 30 per cent. of copper.

In November, 1907, a trial shipment of about five tons of the highest grade ore was raised, carted to Onslow, and shipped to England. According to the figures courteously given to me by Mr. Finch, it appears that the parcel weighed 5 tons 19cwts. 2qrs. 1lb. This ore assayed 21.63 per cent. of copper. The assay on dry ore being:—

Copper 20.33 per cent.
Silver 2ozs.
Gold .20ozs.

The smelting costs on a parcel of ore of this grade and tonnage were £13 15s. and the transport charges from Liverpool to London were £6 15s. 7d., making in all £20 10s. 7d. The value of the ore therefore was £12 9s. 4d. per ton, from which mining costs, transport from the mine to the coast and ocean freight to London had to be deducted. Details as to these latter costs were not available other than that of the transport to Onslow, amounting to £4 10s. per ton; it will, however, readily be seen that there can be little if any margin of profit left unless on a deposit both larger and richer than this one has up to the present proved to be.

About 11 chains south-west of the main shaft two copper-bearing veins have been opened up in a trench 65 feet in length put in on a bearing of 262 degrees. This trench which has an average depth of about two feet exposes on its western extremity a vertical vein of copper-bearing quartz about 12 inches in thickness.

About 40 feet from the eastern end is another quartz reef about four feet thick which connects with that previously described at a point about 40 feet south of the trench, but no other work has been done. This vein can be followed along the outcrop to a point 175 feet north of the eastern end of the trench, where it has been opened out. At this point the quartz is about three feet in thickness and carries a little copper ore, but no other work has been done upon it. A sample of this ore [7735] yielded on assay in the Departmental Laboratory 4.75 per cent. of copper with neither silver nor gold.

At a point near the western boundary of the old Star of the West, M.L. 25, indicated on the map by (a) is a short thin vein of

quartz parallel to the bedding planes of the phyllites, which carries a little green carbonate of copper. From what can be seen the copper is more or less confined to a band near the centre of the vein, which weathers into a very honeycombed mass, containing both green carbonate of copper and oxide of iron, which probably owe their origin to the sulphides of copper and iron.

Several other of the quartz veins which traverse the property are more or less cupriferous; these have been in all cases indicated on the map.

Pedan South, M.L. 61.—This lease adjoins the Pedan on the south and was applied for in 1907 and embraces the greater portion of the old lease known as Long Tom North Extended, M.L. 22. There is no shaft on the ground, the only work done being a little costeaning, etc. The most important featnre on the property is the large quartz reef near the centre of the lease and which has been cut off on the east by a north and south fault. The quartz reef makes a very pronounced outcrop and contains a little copper ore on the walls as well as a very little disseminated through it. The deposit however is too poor to warrant very much work being done upon it. No ore has been raised from this property.

Long Tom North, M.L. 21.—The old Long Tom North lease is traversed by several well-defined quartz reefs one of which (g) on the map is more or less copper-bearing. The ore-bearing belt is traversed near the southern end of the property by a wide alluvial flat, which ultimately loses itself on the sandy granitic plain on the eastern side of the hills.

One very pronounced vein (g) rises to a considerable height about the northern margin of the alluvial flat and carries more or less copper. The ore occurs in a very short shoot which had been opened out and proved to be about four feet long and twelve inches in width in its widest part. The shoot however had not been followed down, so its exact extent could not be defined. A sample of the green carbonate ore, which is the prevailing type, yielded on assay at the hands of Mr. Simpson in the Departmental Laboratory 47.36 per cent. of copper, 0.10 per cent. of lead and 1oz. 5dwts. 19gr. of silver to the ton.

Near the north-west angle of the Long Tom North but to the westward of the boundary is another very well-defined copper-bearing quartz reef about 15 chains in length. It contains, however, copper at only two points along the outcrop about 10 chains apart; it is of interest as proving that the ores of copper cover a fairly wide belt.

Long Tom, M.L. 8.—This lease was applied for in 1901. The same copper-bearing quartz vein opened out at (g) in the adjoining lease to the north crosses the alluvial flat and occupies a considerable portion of the western margin of the lease. At a point (d) about 800 feet south from (g) the lode has been opened out for a length of 15 feet to a depth of not more than six feet. In the open-

cut at the south-western end the copper ore is about three inches thick, whilst at the northern end it has widened out to from six to seven inches. So far as may be judged by the ore now lying on the surface it is quite evident that in one part of the open-cut, the shoot of ore must have been a foot or more in thickness. The ore consists of atacamite, chrysocolla, malachite, and tile ore, in a quartz reef. The lode has an average underlie of 65 degrees to the east. More or less copper ore can be seen all along the outcrop of the vein to the north.

Two other parallel quartz veins, indicated on the map, also carry a little copper ore in many parts, but not in sufficient quantity to be worth opening up.

Part of the ground embraced by this lease includes the property now known as the Phoenix Copper Mine, M.L. 52, applied for by Mr. Yelland in 1907. No survey of the lease having been made it has not been possible to indicate its boundaries on the geological map.

Yanarie, M.L. 73.—This property, which was applied for in 1907 by Mr. F. L. Finch, includes a portion of the Long Tom lease but owing to no survey having been made, its boundaries cannot be even approximately shown on the geological map.

Nankavell's Lode.—What is known as Nankavell's Lode is the southern extension of that traversing the Long Tom lease (q.v.).

The lode after crossing the boundary at about three chains from the south-western angle of the lease presents a continuous outcrop of a little over 20 chains in length. It is interrupted in two places by well-marked faults, the position of which has been indicated on the plan. The outcrop is crossed by an alluvial deposit formed by a creek which ultimately loses itself on the granite plain to the north east.

Nankavell's lode consists of a quartz reef of very variable size, containing more or less copper ore, sometimes in the reef itself and sometimes at others on either wall. The reef dips north-east at a high angle, and near its south-eastern extension is a hematite-limonite vein [7737] from twelve to eighteen inches in thickness containing a little green carbonate and chloride of copper. An assay of it in the Survey Laboratory gave 5.00 per cent. of copper, 33.97 per cent. of iron and a minute trace of gold per ton. This iron lode passes by imperceptible gradations into a pure quartz reef carrying a little green carbonate of copper. Ten feet to the west of this is a very thin vein of good copper ore containing green carbonate and copper glance, but there is no great quantity of it, for the vein rapidly peters out in both directions.

About ten chains north-east is a well-marked limonite lode which can be followed along the surface for about 10 chains; it dips to the north-east at a very high angle.

The group of copper deposits described above appear to disappear, as may be seen by an inspection of the map, at some distance south-east from Nankavell's lode. A very prominent quartz reef indicated by a cairn marks the limit of their extent in this direction.

A parallel group of thin quartz reefs, some of which are copper-bearing, make their appearance to the south-west in the neighbourhood of the Dark Horse lease. The deposits, however, are not, as the map shows, very extensive, and only one or two contain any copper ore.

Dark Horse, M.L. 32.—This twenty-acres lease was applied for by Mr. W. T. Campbell in 1901, and a very little desultory work done upon it. In 1907 a P.A. 13 was taken up by Messrs. Horne, White, and Henry, on that portion of the lease which included the main lode.

The main lode lies in a belt of white silky micaceous schist, a hematite-phyllite [7732] which forms a band of about 20 chains in width resting conformably upon a massive bed of quartz conglomerate and covered by quartzite, the whole series dipping north-eastwards at an angle of 65 degrees.

The main lode has an average strike of about 153 degrees and a length of 24 chains. The lode has been opened up along the outcrop by a shallow shaft 16 feet deep. In the shaft the lode is seen to consist of a very bunchy quartz reef of variable thickness. The quartz [7739] contains small quantities of green carbonate of copper and small grains of copper glance. Nearing the bottom the copper became concentrated into a vein of copper glance varying from four to six inches in thickness. A sample of it [7740] assayed in the Survey Laboratory 55.73 per cent. of copper, a minute trace of gold, and 10ozs. 15dwts. 15grs. of silver per ton.

About 27 feet north of this and 29 feet east of the outcrop, a vertical shaft 48 feet deep has been sunk through fine silky mica schist (phyllite), and in a crosscut to the west and eight feet from the shaft the lode had been met with and proved to be of the type exposed at the surface, but very much thinner where it was struck.

The main lode contains more or less copper along the outcrop, but so far as can be seen the ore seems to be concentrated in close proximity to the shaft.

About a chain east of the shaft is another thin quartz vein which can be followed more or less interruptedly for about three chains north-west. At one spot (t) a little prospecting has been done upon it. At this point the lode has been opened out on the eastern wall and consists of quartz (with kernels of black mica) encased in silky micaceous schist dipping at a high angle to the east. The vein is about six or eight inches in thickness and carries a little green carbonate of copper on the fissures by which the stone is traversed.

The same vein has been opened up at a spot about 150 feet further to the south on its western side. The trench exposes about 12 to

The Hon: H. Gregory M.L.A.
Minister for Mines

PLAN OF
THE UAROO SILVER-LEAD LODE

UAROO

ASHBURTON G. F.

BY

A. Gibb Maitland

GOVERNMENT GEOLOGIST.

0' 100' 200' 300'

Scale of Feet.

R. H. Irwin del.

H. J Pether, Government Lithographer, Perth, W. A.

18 inches of solid quartz with black mica and a little malachite. As a whole, however, the ore is of extremely low grade.

The Uarco Silver Mine, No. 1, M.Ls. 43 and 49.—What is now known as the Uaroo Silver Mine was originally taken up in 1901 by Mr. M. W. Fitzgerald, under the name of the Rainbow Reward Silver Mine; it however became void in October, 1902, though it was not until 1907 that the area was re-applied for by Mr. W. T. Campbell; the property being then known as the Uaroo Silver Mines, M.Ls. 43 and 49.

As at present held the property does not appear to include the whole of the outcrop of the lode, a large scale plan of which forms Plate V.

The lode itself is the most southerly of any of those which are being worked along the Uaroo mineral zone and would appear to have been discovered in 1901 by Mr. Fitzgerald to whom a reward lease was eventually granted.

As may be noticed by an inspection of the Geological Map the lead lode lies in the centre of an area traversed by very many large quartz reefs of the type which characterise those at the northern end of the zone, near the Pedan Copper Mine.

The country rock in the vicinity consists of beds of conglomerate, quartzite, and micaceous slates and schists dipping at very high angles to the north-east and trending north-west and south-east.

Some of the conglomerate beds and quartz reefs are as may be seen by the map (Plate III.) intersected by faults transverse to the general strike of the beds. These faults do not, so far as any evidence at present goes, appear to have any effect upon the lead lode, although the mapping would lead one to suspect the possibility of it being along a line of fault.

The Uaroo Silver Lead Lode trends generally north and south and has an average underlie to the east of about 70deg. The outcrop can be traced along the surface for a distance of over 800 feet, tapering out gradually at either end; the outcrop rises gradually to about 80 or 90 feet above the level of the extensive plain, along the western margin of which it is situated. The highest summit of the outcrop is at a point (a) where the greatest amount of work has been done and from this point it falls away gradually in a north and south direction.

Throughout its whole length the lode is enclosed in nearly vertical beds of gritty sandstone, quartzite, and conglomerate.

The lode is a quartz reef of very variable dimensions.

At a point about 440 feet from the northern end of the outcrop and at what is known as No. 2 tunnel, the lode appears to bifurcate the eastern branch (which on the surface appears to be barren), being nearly 300 feet in length and rejoins the main vein at a point

about 100 feet north of the southern end of the outcrop and half way down the slope of the hill.

A vertical shaft 50 feet deep has been sunk between the main lode and the eastern branch at a spot indicated on the mine plan.

From the foot of the shaft a crosscut has been carried west about 15 feet to the main lode which had been opened out for about 33 feet south; as exposed in the drive the lode proved to be about three feet in thickness and to be of the usual type. The bottom of the shaft and the whole of the crosscut are in quartz which may either represent a local silification of the country rock or the western branch of the main lode.

At the time the mine was visited not very much development work had been done upon it, although a fair quantity (over 10,000 tons) of lead ore had been raised since the date upon which mining operations first commenced.

In addition to the shaft previously referred to the lode has been opened out at different levels by means of three tunnels (adits) put in at different levels, and in the positions shown on the plan (Plate V.). No. 3 tunnel struck the lode at 168 feet from the mouth, after having been carried through highly inclined siliceous sediments of the usual type. Wherever exposed in the workings the lode consisted principally of quartz, but in many portions there were fairly large bodies of pure galena, with now and then small quantities of green carbonate of copper. As followed along the outcrop to the south the copper seems to increase though in no case does it appear to be in any relatively large quantity. The lead ore contains more or less silver, as may be seen by the returns set forth in the Table attached.

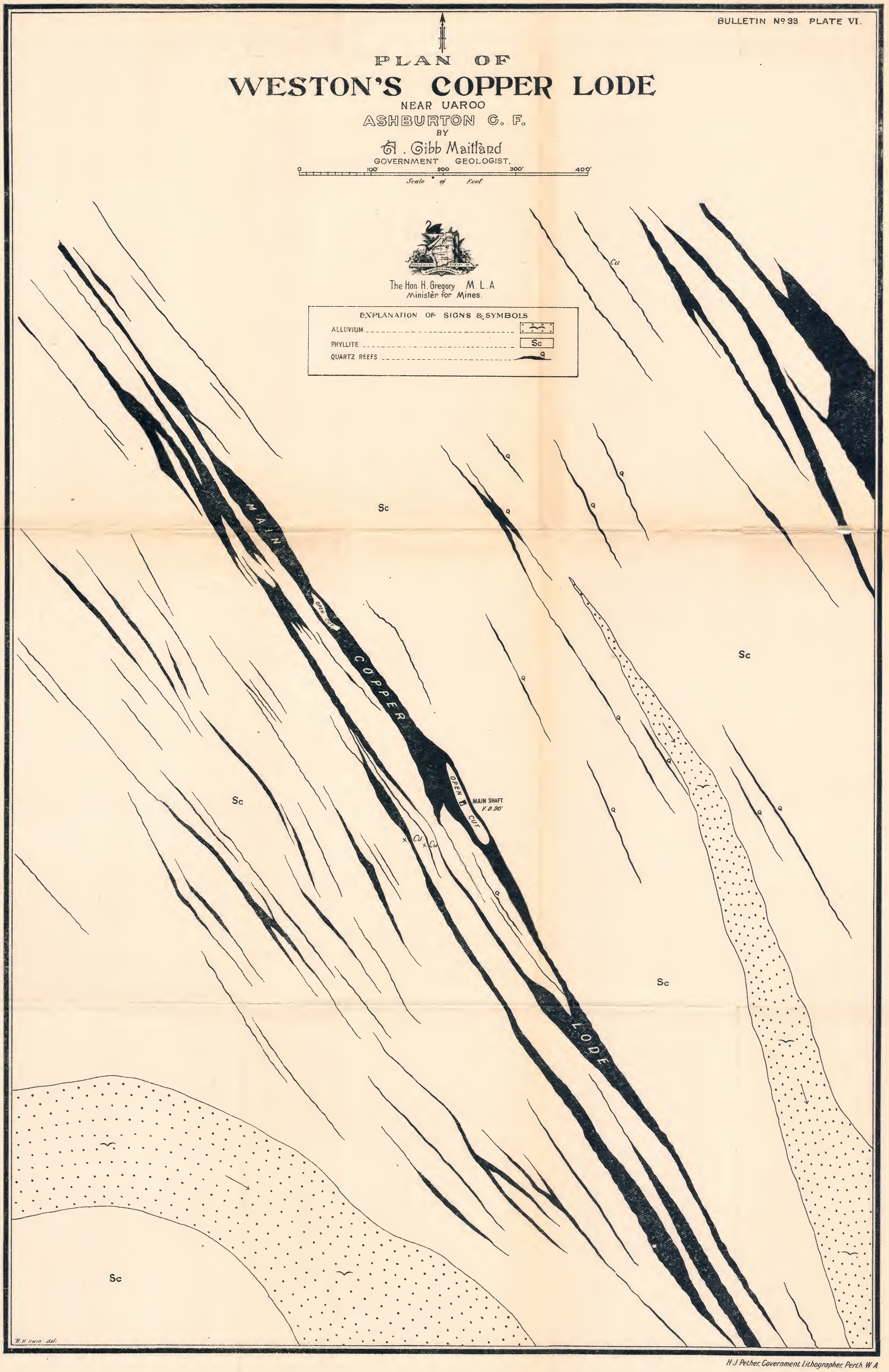
Table showing the Yield of the Uaroo Silver-Lead Lode.

Year.	Name and Number of Lease.	Ore raised.	Value.	Total.	
				Ore raised.	Value.
		tons.	£	tons.	£
1901	Rainbow M.L. 3 ..	*9·09	†109·00	..	..
1902	Do.	35·85	‡277·00	44·94	386·00
1907	Uaroo Silver Lead Mine, M.L. 43/49	272·95	§3,497·00	..	..
1908	Do. do.	727·25	6,914·00	1,000·20	10,411·00
	Total	**10,045·14**	**10,797·00**	**10,045·14**	**10,797·00**

* Mr Göczel, noted that about 70 tons of high grade ore were bagged on the surface at the time he inspected the property in 1901. † Returned 356·26 ozs. of silver, valued at £43. ‡ Returned 626 ozs. of silver and 18·76 tons of lead. § Export figures.

ETIN Nº 33 PLATE VI.

Pether. Government Lithographer. Perth. W A.



H. J. Pether, Government Lithographer, Perth. W. A.

WESTON'S COPPER LODE AND VICINITY.

(Plan Plate VII.)

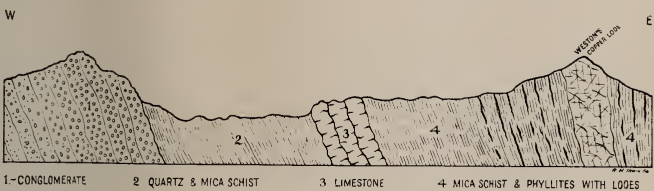
Having completed investigations at Uaroo, camp was shifted seventeen miles to the westward to what is known as Weston's Copper Lode, in the vicinity of which a few days were spent.

From camp at Uaroo to Weston's the whole country passed over consisted solely of sedimentary rocks of the Uaroo type. Interbedded with the quartzites, conglomerates, etc., are beds of dolomitic limestone, lithologically identical with those exposed at Coorara and referred to on an earlier page; all the beds are very highly inclined and have a general strike of north-west and south-east.

The strata in the more immediate vicinity of Weston's consist of coarse calcareous grit (arkose) [**7748**] and impure quartzite [**7749**] both of which have been subjected to a considerable amount of crushing; these rocks have been fully described in Mr. Thomson's Petrological Notes. Associated with these are bands of limestone and phyllite. A well cleaved silvery tourmaline-phyllite [**7750**] forms the matrix of the lode.

Similar sedimentary beds occupy the country westward to a point about a mile to the west of Arrijool Windmill on P.L. 2588/102,* which lies about 12 miles east of Messrs. Cameron and Clerk's Station, Wogoola. The beds consist of nothing but quartzites, grits, and conglomerates of the type occurring at Weston's, of which series they form a part. In one place the beds are associated with limestone (dolomite?) and there are also many bold quartz reefs traversing the whole series as at Uaroo and Weston's. About a mile west from Arrijool Windmill granitic rocks with micaschists or gneiss make their appearance and form the floor upon which these ancient sedimentary series were laid down.

A few traverses in the more immediate vicinity of Weston's indicated the general sequence of the beds to be as shown in the section, Fig. 29; no base however was seen until Arrijool well was reached, hence it is more than probable that the beds have been repeated several times by folding.



SECTION IN THE VICINITY OF WESTON'S COPPER LODE

Fig. 29.

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* Lands Department 300-chain Lithograph 94.

Weston's Copper Lode makes a very bold outcrop, extending for a distance of about 2,000 feet in a north-west and south-east direction as may be seen on the plan, which forms Plate VI.

The lode itself is merely a quartz vein, about 50 feet in width in its widest part, and merely forms part of a silicified and sheeted zone in a silvery tourmaline-phyllite [7750]. A photograph of the outcrop of the lode near the main shaft forms Fig. 30. The width of the zone is about 400 feet, though the ores of copper seem to be confined to the veins in the more immediate vicinity of what may for convenience be called the main vein.

Fig. 30.

OUTCROP OF WESTON'S COPPER LODE.

A careful inspection of the outcrop shows that the system of quartz veins is traversed by several minor fractures, approximately at right angles to the general trend of the zone; whilst what little work has been done underground discloses a second set of fractures (joint planes?) which are practically horizontal. It has been found that at the intersection of these two fractures rich pockets (almost flat floors) of copper ore frequently occur.

An attempt has been made to show this relationship in isometric projection in the diagram which forms Fig 31.

GENERALISED SECTION IN ISOMETRIC PROJECTION
SHEWING THE MODE OF OCCURRENCE OF THE COPPER ORE
AT WESTON'S MINE NEAR UAROO ASHBURTON G F.

Fig. 31.

Only a very little work had been done on the deposit at the time of my visit to the district. At that time the lode was being exploited in two localities. The most northerly consisting of a shallow open cut about 60 feet in length from which a very small quantity of low-grade ore had been raised. About 250 feet to the south-east of this was a shallow open cut about 130 feet in length, in which a main shaft is situated. The shaft had been carried down to a vertical depth of 90 feet, without however disclosing any ore of importance. At 30 feet from the surface two short crosscuts had been put in at right angles to the general trend of the lode, and a small quantity of copper ore obtained from what appeared to be a horizontal vein, which merely represents one of the flat floors to which allusion has already been made.

Those in charge of the operations at the mine informed me that so far as work has at present been carried the shoots of ore have a tendency to dip south and to trend parallel to the strike of the country rock, though there are here and there cross veins to which reference has already been made.

Two trial parcels of picked ore comprising $16\frac{1}{2}$ tons and 7 tons respectively were forwarded to the Fremantle Smelters and returned, I am credibly informed, 35 per cent. of copper, 10ozs. of silver and no gold.

The ore which makes up Weston's lode consists essentially of quartz, a little green carbonate of copper, copper glance (chalcocite) small quantities of hematite, titanite, and a little black mica. Some of the larger masses of copper glance [7753] contain fragments and broken crystals of quartz, the surfaces and cracks in which are coated with a film of a green mineral, which may be malachite. Free gold is showing in some of the copper-bearing quartz [7754].

There does not appear to be any record of the quantity of ore raised from the property; it can however be only very small.

Many of the smaller quartz veins shown on the plan, Plate VII., carry small quantities of copper in certain localities, but in no case in anything like commercial quantities.

About a quarter of a mile north-east of Weston's is a new find of copper ore. It proved to be of the same general type as that previously described. The outcrop of the quartz vein stood up in bold relief, and trended across country for some distance; a few shots had been put in at one spot, and exposed a few lenticular veins of green carbonate of copper. No other work had been done.

About six miles north of Weston's are what are known as the Euro Leases, held by the same owners, but no work whatever was going on at the time the locality was visited. The lode which is in the same mineral zone as that of Weston's is about a mile in length and attains a maximum thickness of 50 feet. The lode is merely a mass of quartz veins and leaders containing more or less copper which in some portions is concentrated into small lenticular patches, which seemed to justify a little work being done upon them. In one spot a vertical shaft had been sunk to a depth of 50 feet, but I was credibly informed it failed to pick up anything of value. The ore consisted chiefly of malachite with a little azurite, chalcocite, and in parts small quantities of a white metallic mineral [7755] which on examination in the Departmental Laboratory proves to be Seleniferous Tetradymite (Sulpho-telluride of bismuth).

Some of the quartz shows a little gold in places and it is instructive to note that about 60ozs. of alluvial gold have been obtained from some of the smaller gullies in the vicinity of Weston's.

On the whole it appears that the district in which Weston's is situated is a mineralised one, though up to the present time it cannot be said that any very valuable deposits have yet been discovered or opened up; there is, however, the possibility of such ore deposits being found along the belt.

THE COUNTRY BETWEEN WESTON'S AND THE CANE RIVER MINES.

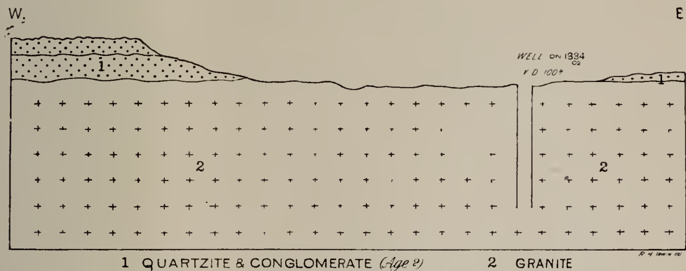
(Geological Sketch Map, Plate I.)

Having completed investigations in the vicinity of Weston's a traverse to the Lyndon River valley was made, with the object of gaining additional information, and from thence to the upper reaches of the Cane River to examine the copper mine which was being worked at that centre.

Leaving camp at Arrijool Windmill* to which reference has already been made the track to old Tower House on the Yannerie River was followed.

The highly inclined sedimentary rocks crossed between Weston's and Arrijool gave place at a mile west of the windmill to granitic rocks and micaceous schists. As seen in numerous exposures on the Yannerie River, these crystalline schists are intersected by numerous pegmatitic granite veins, which in some places contain tourmaline in large quantities, so far as could be seen the veins have no prevailing direction.

From Tower House our route lay generally south-west to a well on Location 1334/102* which had been put down to a depth of about 100 feet in granite.



SECTION AT THE HEAD OF THE LYNDON RIVER

NOT TO SCALE

Fig. 32.

About a mile or so from the well the outcrop of a nearly horizontal sedimentary series makes its appearance in some low table-topped hills. One of these about two miles south of the well was ascended and was found to consist of quartzite with a considerable development of secondary silica. The low ground in the vicinity of the well is in places covered by a ferruginous fine-grained conglomerate, which in all probability forms the basal member of the series as developed in this district. The conglomerate is very thin but its remnants cover a fairly wide area; it may represent the base of the Carboniferous Rocks exposed in the vicinity.

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* Lands Department 300 chain Lithograph 94.

From this well our route lay generally west as far as Windalia Pool (the only available water) on the Lyndon River. The bank of the river at the pool expose a fine-grained argillaceous sandstone or sandy shale.

About two miles to the north is a table-topped hill upon which the cairn A46 had been erected; the strata exposed on the hill consisted of horizontal beds of fine-grained false-bedded and argillaceous sandstone, overlaid at one end of the hill by a thin band of a fine-grained quartzite conglomerate.

From Windalia Pool a visit was paid to the country in the vicinity of Tchugareywurdoo Pool, to examine the boulder bed the existence of which had been previously noted.*

The boulders consist of a great variety of rocks and many of them are covered with glacial striae; the bed wherever exposed is in every way identical with those on the Gascoyne, etc., to which reference has already been made. Its stratigraphical position, beneath the fossiliferous limestone, of carboniferous age, shows it to be identical with the glacial conglomerate of the Arthur and Minilya Rivers.

From Windalia exigencies of travel took us southwards as far as the dam on Kialawibri Creek, where it is crossed by the road from Maud's Landing. The debris of the glacial conglomerate was frequently exposed en route. From the dam our route lay generally south-eastwards and passed between the range of flat-topped hills upon which Trig. Station A. 42 rests and the Pleiades. No section of the underlying strata was seen though the debris which strewed the surface indicated quite clearly that the flat-topped hills were covered with quartzite.

Ultimately the road left the sedimentary beds and their place was taken by the crystalline schists. From this point the road to Lefroy's Station on the Lyndon River was followed, and from thence in a general north-easterly direction by a road which passed to the south of Winning Cairn. The rocks exposed en route were found to consist of crystalline schists (? metamorphic sedimentary rocks) invaded by dykes and masses of granite.

About four miles from our camp at the Roads Board Well the crystalline schists gave place to highly inclined quartzite and slate, the relation of which to the crystalline schists were not clear. These sedimentary rocks occupied the country for a mile or two when their place was taken by granite which occurred in great force in the watershed of the Yannerie River.

Camp was pitched at the Well 38† on the DeGrey-Mingenew stock route. The well itself was only shallow and was sunk in granite. About a mile south-east of the well is a bold quartz reef having a

* On the Country between the Ashburton and Minilya Rivers with a view to determining the Northwards extension of the Gascoyne Artesian Area. H. P. Woodward. Geol. Surv., Bulletin 26, Perth: By Authority, 1907, p. 12.

† Lands Department 300 chain Lithograph 93.

general strike of north 30 degrees east. The reef which is vertical is about 20 feet thick in its widest part and is enclosed in fine-grained granite.

At Well 39 along the stock route is granitic schist but between this and Well 40 are vertical beds of mica schist with intrusive granite and quartz reefs; there are also a few very fresh-looking greenstone (dolerite) dykes.

Due west of the Well 40 is a fairly extensive tableland upon which Trig. Station H. 21 stands. This plateau is made up of fine, gritty sandstone (often weathering into caverns) and quartzite; the beds being inclined at a gentle angle from the horizon. They rest with a violent unconformity upon the older crystalline schists, etc. The beds of this tableland may represent the remnants of the western extension of the horizontal strata which form the north and south range upon the northern end of which Mt. Florry is situated, as well as those of the Barlee Range.

From Well 40 the main road down the valley of the Henry River was followed as far as Glen Florrie outstation, known and shown on the maps as White Rocks. Some distance after leaving the well the country was occupied by vertical beds of coarse micaschist with masses and veins of intrusive granite and pegmatite granite. About eight miles north of the well and on the east side of the road is a low tableland of quartzite and quartz conglomerate, identical in every way with that seen at H. 21. From this point the older underlying beds vary very much in texture and they are interbedded with beds of limestone (marble) which cover a wide expanse of country. These marbles continue as far as the station at White Rocks on the Henry River. East of the limestone at the station beds of coarse micaceous schist outcrop. It seems perfectly evident that the calcareous strata are identical with those at Coorara, to which reference has already been made.

Between the White Rocks and Glen Florrie Station the strata exposed consist of micaschist and granite of the usual type.

From Glen Florrie across country to Coorara Claypan micaceous schists of sedimentary origin invaded by masses of granite and dykes of grano-diorite prevail. Crystalline limestone (marble) is also associated with the micaceous beds an exposure of which may be seen in the Ashburton River near the crossing at Coorara.

From Coorara exigencies of travel took us to Metawandy Creek via Higham's outstation and thence to Mount Stuart, which lies due north of Reserve 1108 on Duck Creek.* Mount Stuart forms the culminating point of a little *massif* which rises boldly from and forms a conspicuous feature in the level plains by which it is surrounded on all sides. The staple formation in the vicinity was found to consist of greenstone schists of the type common to many of the West-

* Lands Department 300 chain Lithograph 96.

ern Australian Goldfields. The southernmost spur of Mount Stuart consists of a band of laminated hematite-quartzite [7756] striking generally 135 degrees and underlying to the eastward at a high angle.

An analysis of this ore at the hands of Mr. E. S. Simpson in the Survey Laboratory gave the following results:—

$Si\,O_2$	40·21
$Ti\,O_2$	*Nil*
$P_2\,O_5$	·24
$H_2\,O$ (comb.)	·97
$K_2\,O$	·39
$Na_2\,O$	·52
$Ca\,O$	·23
$Mg\,O$	·33
$Mn\,O$	1·14
$Fe\,O$	*Nil*
$Fe_2\,O_3$	54·75
$Al_2\,O_3$	1·80
$Fe\,S_2$ { Fe	·04
$Fe\,S_2$ { S_2	·05
$H_2\,O$ (hygrosc.) ...	·05
	99·72
Sp. Gr. (approx.) ...	3·58

Mount Stuart is composed of a succession of these banded ironstones which may however merely represent the same bed repeated by folding. Some of these ferruginous bands are very minutely puckered. In addition there are also numerous bands of felspathic schist (? argillaceous sandstone) the weathered surfaces of which are stained with black oxide of manganese, giving a peculiar glazed surface to the rock, and giving the impression of a huge ironstone lode. On the western slopes of Mount Stuart is a bed of sheared impure quartzite [7757].

This district was visited by the late Mr. Walter J. Kohler, who in his report thus described Mount Stuart:—

> The next thing that claimed my attention was an outcrop of manganiferous ironstone; an analysis showed 10 per cent. of manganese. . . .
>
> This outcrop is traversed by numerous quartz stringers, and altogether it is by far the largest outcrop I have ever seen, surpassing even Broken Hill. It has the appearance of a true reef between slate walls. Its general trend is slightly west of north and east of south. The width seems to vary between 60 and 100 yards, and more, and its length is at least 1½ miles. The outcrop is fully 200 feet above the level of the surrounding flat country. Various samples taken carry traces of gold, silver, and copper, one assay giving 3 dwts. of gold. I have no hesitation in stating that the property is well worth prospecting, even to the extent of several thousand pounds, as should it prove to be only moderately auriferous and cupriferous it would be very payable. This is what is known as Mount Stuart, and is a prominent landmark.

It is not quite clear from the above description whether the deposit which Mr. Kohler describes is that which was visited by myself

but it is evident that the lode to which he alludes is of considerable size and some importance.

A lead and copper lode outcropping on the flat at the foot of the western slope of Mount Stuart had been worked at one time, but there does not appear to be any record of the quantity of ore turned out. The lode so far as could be seen trended generally east and west and consisted of the usual characteristic schistose formation, carrying a little copper and lead along the bedding (? foliation) planes; the formation was traversed by quartz veins and leaders, some of which seemed to be of considerable dimensions.

A little desultory work had been done at the eastern end of the outcrop but as operations are said to have ceased about seven years ago, there was little or nothing to be seen. Near the western end of what is believed to be the same lode is a vertical shaft 30 feet in depth but inaccessible to me. From what little could be seen it appears that the lode has a slight underlie to the north. The small quantity of ore lying at the shaft consisted of quartz with a little green and blue carbonate of copper, yellow oxide and carbonate of lead, together with variable proportions of oxide of iron. The best ore has undoubtedly been removed. The rises on the low ground consisted of schist, dipping to the north, and associated with a band of sheared conglomerate [7757] a full description of which is given in the Petrological Notes.

From Mount Stuart exigencies of travel took us to Mistake Well, No. 43. The hills to the west of the well are made up of laminated quartz and iron-bearing schist of the Mount Stuart type; these trend generally northwards, dip to the west and are traversed by quartz reefs.

From Mistake Well we travelled to the Cane Copper Mine, which is situated on the headwaters of the Cane River, some distance to the south of Red Hill.*

THE RED HILL DIGGINGS.

(Geological Sketch Map, Plate I.)

From the camp at the Cane River Mine opportunity was taken to make a more or less detailed investigation of the various ore deposits which had been worked in the vicinity. The first mine examined was the Cane Copper Mine.

Cane Copper Mine, M.L. 62. Plan (Plate VII.).—The ground which now embraces the Cane Copper Mine appears to have first been applied for in November, 1899, under the name of the Red

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* Lands Department 300 chain Lithograph 96.

Hill Copper Mine, M.L. 1. Twelve tons of ore were sent to Dry Creek Smelting Works, South Australia, and it is stated that the grade of the ore was good, but the heavy transport charges left the owners no profit. The lease was surrendered in March, 1901, but was subsequently taken up again in April of that year and the name eventually changed to the Westralian Moonta Copper Mine, M.L. 9. In February, 1900, another copper mining lease of 30 acres (M.L. 2, subsequently No. 7, Cane River) was taken up adjoining the eastern boundary of M.L. 1, and a similar area on its western boundary (M.L. 3, and subsequently No. 8, Cane River). In its present form the Cane Copper Mine was applied for in May, 1907, by Mr. R. A. Black, the boundaries of the lease embracing portions of the abandoned holdings previously alluded to.

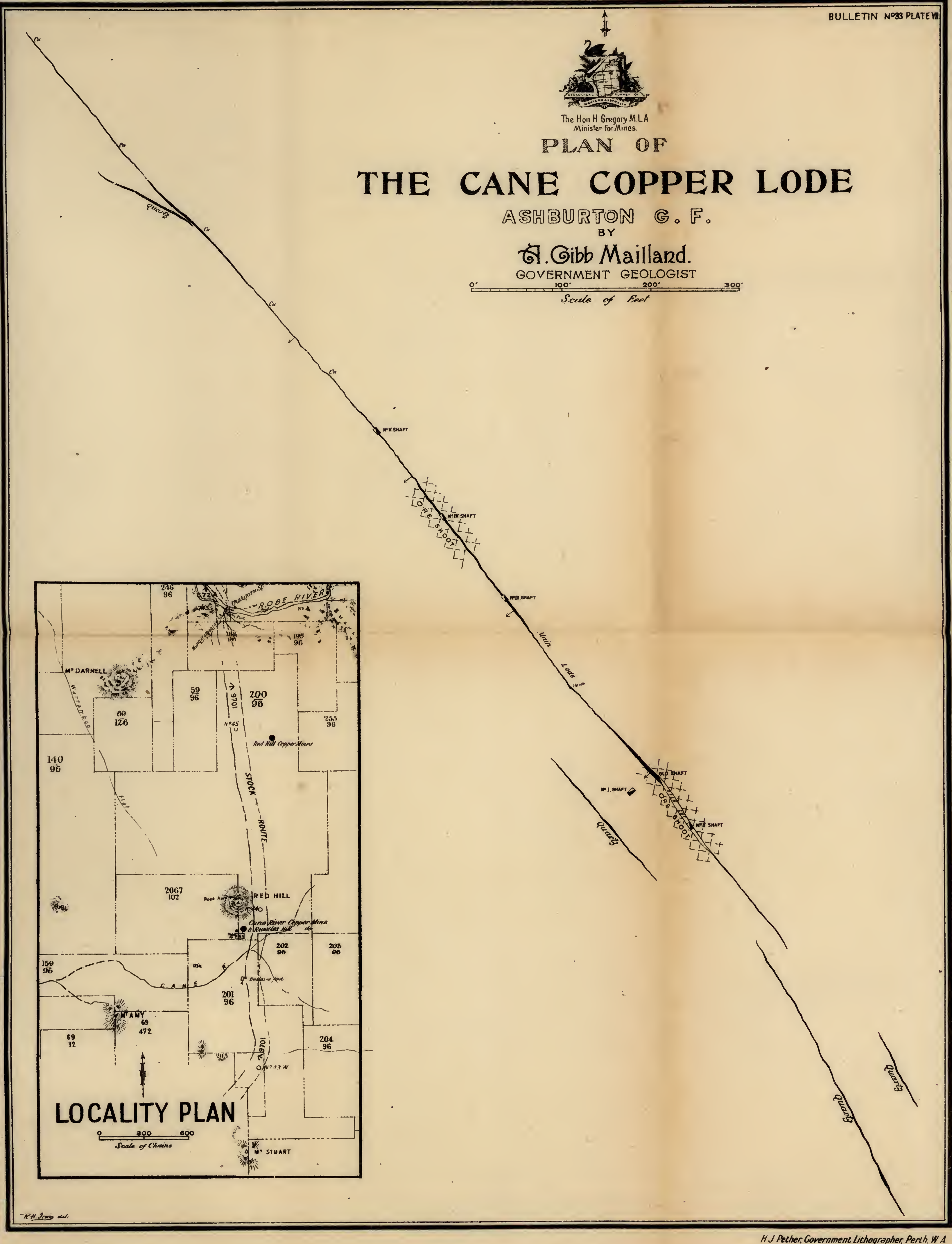
The Cane Copper Lode is situated on one of the tributaries of the Cane River, about 2½ miles south of Red Hill (there are two such) of the maps and about two miles from the limestone hill alongside the main road to Roebourne, and locally known as Rundles Hill.

The lode which outcrops on the level ground some considerable distance away from any of the hilly country can be followed continuously for about 1,400 feet on an average bearing of N. 35 deg. W. The lode has a high underlay in a south-westerly direction. The lode is a quartz reef containing the ores of iron and copper in varying proportions.

The ore-carrying matrix is quartz [7763] which in certain places is traversed by minute veins and kernels of copper pyrites and its decomposition products. Portions of the outcrop carry fairly large quantities of "tile ore" [7762], the red oxide of copper and iron, whilst others contain relatively large proportions of copper glance (chalcocite) [7758, 7759].

At both ends of the outcrop the main lode gradually tapers out into the enclosing schist which forms the matrix. At the southern extremity of the outcrop and about 20 feet west of the main lode another well-defined quartz reef makes its appearance and can be followed for over 300 feet in a direction parallel to that of the main lode. This quartz reef also carries a little copper ore [7763] but so far as can be seen on the surface not in such quantities as to make its exploitation commercially profitable. An assay of the sample [7763] in the Departmental Laboratory yielded 1.09 per cent. of copper.

The main lode was being worked by means of four shafts, the relative positions of which are indicated on the plan of the Cane Copper Lode, which forms Plate VII. In addition to these a block shaft, No. 1, was being sunk at a point about 30 feet



H. J. Pether, Government Lithographer, Perth, W.A.

south-west from the outcrop of the lode, not far from the old opencut, 100 feet in length, which was put in by the previous owners of the property. From this opencut the previous owners are stated to have raised about 44 tons of high grade ore during the period the ground was being worked. All the shafts and opencuts show the lode as being practically vertical for the first 10 or 12 feet, and then gradually to flatten out to its ordinary underlay.

Shaft No. II. and the most southerly had been sunk to a vertical depth of 15 feet by the previous owners of the property, some seven years ago and was continued by the present lessees of the ground. The shaft was put down not far from the southern extremity of the opencut 100 feet in length. To the north of the shaft and in the bottom of the opencut about 12 to 14 feet from the surface, there is at the present time two feet of good copper ore showing on the hanging wall of the lode which so far as may be judged attained a maximum width of about five feet. It is stated that when the lode was first discovered it made a very bold outcrop, rising about three feet above the level of the surface and carried very good green carbonate ore. The lode can be followed down the shaft to the bottom, 42 feet in depth, at which depth it had been driven on to the south for a distance of 25 feet. The face of the southern drive exposes about from 8 to 10 inches of ore. The lode had also been followed at this depth about 40 feet north but at the date of my visit the level was not accessible, owing to its having caved in; it is stated however that the drive showed a good strong body of ore, averaging about 2 feet six inches in thickness. Water level occurs at 40 feet at which depth it is stated that there are signs of the copper having been partially leached from the ore. It is apparent that from the above descriptions there is in No. II. shaft a well-defined shoot of ore at least 60 feet in length and of workable width.

The present owners had raised at the time of my visit approximately 60 tons of ore from this shoot, to which must be added the 44 tons taken from the opencut some seven years ago. It was proposed working this shoot of ore from No. I. shaft, which was being sunk at a point about 30 feet south-west from the northern end of the opencut. The shaft was being carried down through soft decomposed micaschist of sedimentary origin.

A few feet from the northern end of the opencut an old shaft 15 feet deep had been sunk on the lode by the previous owners of the property; from what little can be seen at the present time the lode though good is small. From this old shaft the lode can be followed without any interruption though, as might be expected with very varying thickness, to a small pothole about five feet deep and six feet in length; which shows the lode to consist at this point of but a few inches of quartz

with the green carbonate and a little grey sulphide of copper disseminated through it.

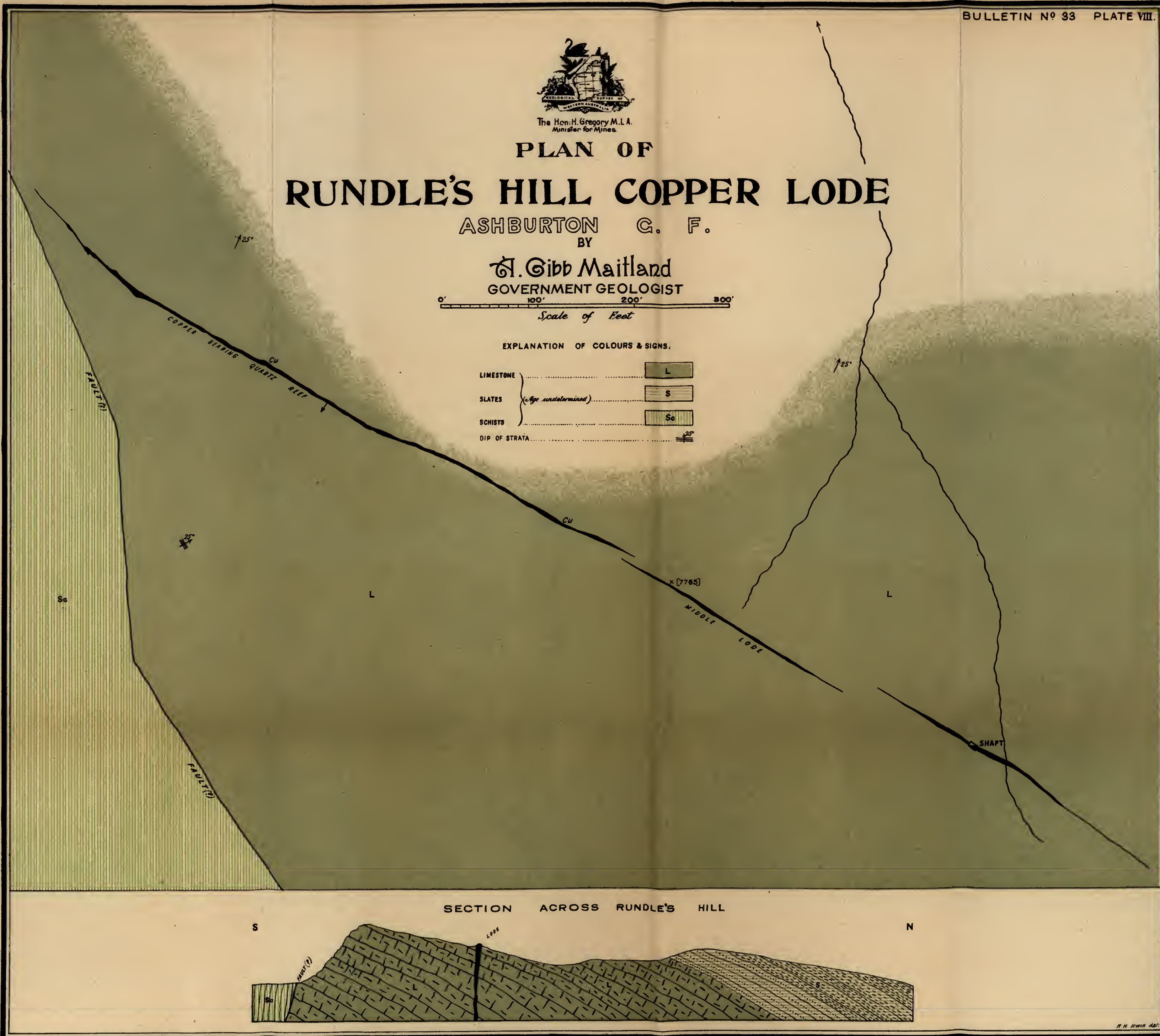
Shaft No. III. is about 130 feet north of this point and the lode can be followed along the surface the whole way. The shaft has been carried down to water level which is about 42 feet below the surface. The lode which is of the usual type goes down persistently to a point about 20 feet below the surface where it peters out and there is no sign of it whatever to the foot of the shaft, although both hanging and footwalls are well-defined. The width between the walls is about two feet; they merely enclose "formation"—shattered or squeezed country rock. It is stated that underfoot at the bottom of the shaft a little copper ore was beginning to make its appearance at water level.

The lode can be followed about 115 feet north to No. IV. shaft which had been carried to a depth of about 42 feet below the surface, the first 10 feet being vertical and the rest on an underlay of about 70 degrees. At 35 feet from the surface drives have been put in north and south along the lode for distances of 42 and 40 feet respectively. In the southern drive the ore, in places, attains a thickness of about three feet, whilst at the face of the northern drive it is but a few inches. A good body of ore has been taken out for a height of about 10 feet above the level of the floor of the northern drive. At the bottom of the shaft the ore is about two feet thick and appears to be going down very strongly. In this shaft there is a well-defined shoot of good ore exposed at the 33 feet level, over 80 feet in length. About 115 tons of ore are stated to have been raised from this shoot at the date of inspection. Some of the ore from near the surface contains a fair quantity of chrysocolla.

The northernmost shaft, No. V., is about 120 feet distant from No. IV., and the lode is continuous between the two points. The shaft has been carried down to a depth of about 42 feet. At the foot of the shaft a short drive 14 feet in length has been put in to the north along the lode, which however, where opened up, is small. There is a thin vein of good ore exposed underfoot on the hanging wall of the lode and it may possibly make into a good body of ore. Some very good grey sulphide ore associated with the green carbonate is showing in the shaft. About five tons of this class of ore had been raised from this shaft at the date of my visit.

As may be seen by the map the main lode can be followed northwestwards from this shaft for a distance of about 700 feet, at which point is gradually peters out. At several points along the outcrop "floaters" of good green carbonate ore [7758] with a little grey sulphide may be seen and so far as may be judged by some they seem to have been derived from bunches several inches in thickness. Their persistent occurrence at intervals along the outcrop for a distance of about 700 feet north of No. V. shaft encourages the belief that

RUN



H.J Pether, Government Lithographer, Perth, W.A.

other shoots or bunches of ore of workable dimensions and of high grade may yet be met with in this direction.

There is hardly sufficient evidence as yet available for any sound deductions to be drawn as to the behaviour of the ore shoots, though it may be mentioned that local opinion inclines to the belief that they will be found to dip to the northwards.

According to information supplied locally, it appears that the cost of mining amounted to about £4 per ton, and transport, smelting, and other charges varied from £6 to £7 per ton, hence it required ore worth at least £12 per ton to be remunerative, even when copper reached the high figure in 1907.

The following table shows the output from this mine, so far as can be ascertained from the official records:—

Table showing the Yield of the Cane Copper Lode.

Year.	Name of Lease.	Ore raised.	Metallic Copper.	Value.
		tons.	tons.	£
*	Red Hill Copper Mine, M.L. 1	44·00	*	*
*	Westralian Moonta Copper Mine, M.L. 9	*	*	*
1908	Cane Copper Mine, M.L. 62 ..	175·50	33·85	2,126
	Total	**175·50**	**33·85**	**2,126**

* No records available.

Rundle's Hill Copper Lodes. Plate VIII.—The Rundle's Hill Copper Lodes are situated at an estimated distance of a mile and three-quarters in a direction bearing 126 degrees from the Cane River Copper Mine.

Rundle's Hill upon which a cairn has been erected lies just to the west of and alongside the main road from Mount Stuart to Red Hill Station and about three miles south of Red Hill. Rundle's Hill forms the culminating point of a low but conspicuous ridge trending generally north-west and south-east and having a length of about a mile and three-quarters; it is formed of beds of dolomitic limestone which seem to have been faulted against the vertical schists, etc., as shown in the section at the foot of the plan which forms Plate VIII. In consequence of the disposition of the strata the ridge presents a bold escarpment to the south-west and a gentler slope of about 25 degrees to the north-east which coincides with the dip of the beds.

The beds consist of dolomitic limestone, covered by quartzites and siliceous sandstone.

The lodes of which there are three are made up of quartz [7764] and occur in the limestone of which Rundle's Hill is made up: a plan of the lodes forms Plate VIII.

The northernmost lode has a length of about 750 feet and an average trend of about north 70 degrees west, and is to all intents and purposes vertical. The quartz reef attains a thickness of seven feet in one place about 150 feet from the northern end of the outcrop: at either end of the outcrop the reef gradually tapers out and eventually disappears. A little work has been done upon the vein at a point A. where it has been opened out for a distance of 17 feet and to a depth of about four feet. The open cut shows about three feet of a copper-bearing reef; the ore consisting chiefly of green carbonate of copper disseminated sporadically through the body of the quartz. In one or two places along the outcrop of this reef there may occasionally be seen a very small vein, merely an inch or two in thickness, of fairly high grade ore.

Commencing at a point about 10 feet south-west of this vein is another parallel quartz reef about 260 feet in length. This vein has been prospected in one or two spots and in one place there is a thin vein of three inches of good green carbonate ore associated with a little oxide of iron. A sample of this ore [7765] assayed in the Survey Laboratory 19.65 per cent. of copper; a minute trace of gold, and 2dwts. 17grs. of silver per ton.

The third parallel reef first makes its appearance at a point north-east of the southern end of the middle lode and about 20 feet to the north of it. The quartz reef can be followed south-eastwards for about 350 feet until it gradually tapers out. A vertical shaft 20 feet deep has been sunk on the lode at a spot about four feet west of the creek by which the northern slopes of Rundle's Hill are drained. The lode, which is of honey-combed quartz, is two feet six inches wide and can be followed down to the foot of the shaft. It contains copper pyrites and its decomposition products disseminated through it. The honey-combed cellular nature of the quartz clearly points to the fact that a very large quantity of ore must have been leached out. A sample of this quartz [7764] yielded on assay 11.59 per cent. of copper. On the hanging wall side of the lode there is a thin vein of fairly good ore about four inches in thickness, exposed in both ends of the shaft, but it does not appear to go down very far. It was probably the occurrence of this shoot which led to the present shaft being sunk.

The limestone which forms the walls of the lode is also impregnated with copper carbonate [7766].

Some distance to the north of this and beyond the limits of the map a little work has been done in opening out a parallel vein of quartz just at the junction of the limestone and the schists. The

vein is very small and contains in addition to some green carbonate of copper a fair quantity of chrysocolla.

There appear to be no records of the amount of copper ore raised from the Rundle's Hill Copper Lodes, the quantity however can only be very small.

The interest attaching to these lodes is the fact that they traverse a much newer series of strata than the schists and indicate that a deposition of the copper ores took place at a much later date than the formation of the underlying schistose rocks. So far there is no evidence as to the geological age of the newer sedimentary series of Rundle's Hill. The beds bear a close resemblance to those at Coorara to which reference has been made on an earlier page.

Locke's Mine.—About three and a-half miles north-west of the Cane River Mine is what is known as Locke's Mine.

The deposit is a quartz reef carrying copper situated in soft fissile phyllite associated with which are limestones of the usual type. No opportunity presented itself of preparing a plan of the deposit hence a verbal description is all that can be given of it. Very little work has, however, been done upon it. The outcrop of the deposit trends generally at right angles to the average strike of the country. A prospecting shaft 16 to 18 feet deep has been sunk to the lode. The reef passes through the shaft at 18 feet and was followed down an underlay of 50 to 55 degrees in a direction of south 35 degrees east for a distance of about 12 feet at which point the vein is represented by a mere thread of quartz. From the foot of the shaft a drive has been put in in the direction of north 35 degrees east for, about 14 feet on the footwall of the lode; in one portion of the drive the lode widens out to as much as 12 inches. The ore raised from the shaft and lying in the dump consists of quartz containing green carbonate of copper, copper glance, and bunches of copper pyrites and tile ore. The vein can be followed on the surface for a distance of about 100 feet in which neighbourhood it gradually peters out. The vein can be followed northwards from the shaft for a distance of about 30 or 40 feet at which point it abuts against a band of almost vertical limestone trending north 40 degrees west and dipping south. A hole about five feet deep has been put down at the northern extremity of the vein and exposes a few inches of quartz carrying a little green copper carbonate, copper pyrites, and "tile ore."

About 150 feet from the shaft in line with the outcrop of the lode and near the junction of the limestone and the other rocks are some east and west veins of quartz, some of which range in thickness between eighteen inches and two feet. These carry small quantities of copper and iron ores of the same type as those in Locke's Lode, but no work has been done upon them.

THE BIG BLOW.—Not far distant from Locke's is what is known as the Big Blow from which the Cane River Lode bears 135 degrees. The name has evidently been derived from the large lenticular vein of quartz, from seven to eight feet wide, which forms part of a system of parallel quartz veins of the type exposed at Uaroo. Several small bunches and shoots of good copper ore occur associated with these veins, but beyond opening out one or two, a few inches in thickness, nothing appears to have been done upon them. This system of veins forms the northern extension of that upon which the Cane River Mine is situated. This long belt is in reality a shear zone in which the ore deposits are likely to persist and to extend to considerable depths. This belt passes underneath and is concealed by a bed of sandstone, etc., trending generally north and south and which may possibly represent an outlier of the Nulagine Series as developed in the Hamersley Range to the west.

HIGHAM'S CANE RIVER COPPER SHOW.—In the year 1899 three leases, M.Ls. 1, 2, and 3, known as the Cane River Copper Show, were applied for by Mr. J. W. Higham. These are situated about 2½ miles from the well on the Cane River known as the Tin Hut.

No work was going on at the time of my visit and I made no inspection, but the following account by the late Mr. Kohler gives an idea of the nature of the deposit:—

. . . . a distinct copper lode about 18 inches wide can be traced for about a quarter of a mile. When I saw this no work had been done on it, but since then a shaft has been sunk to a depth of about eight feet, showing good copper ore to the width of about 15 inches all the way down. A sample assayed 32 per cent. of copper; all this material carries traces of gold and silver. The copper appears as carbonate, silicate, red and grey oxide, chalcopyrite, and bornite. . . Though about 150 miles from Onslow by road, it is only 60 miles from the coast, the nearest point being a place called Burt's Landing, with a good road all the way. . . . On this same property is found a very narrow leader of lead ore, galena, and copper ore, but its small size makes it valueless.

About twenty miles north of the Cane River Mine is a small group of copper lodes, known locally as **The Red Hill Copper Mines** (Geological Sketch Map, Plate IX.) These are situated almost due east of Stock Route Well, No. 45, and distant about two miles from it. It may be noticed in this connection that on the official maps* there are two Red Hills, one near the head of the Cane River, and a second on the northern bank of the Cane River, near Mount Minnie, which forms the northern extremity of the Parry Range. It is much to be regretted that two hills in the same watershed should have been given similar names. It is due north of the former Red Hill that the copper lodes are situated.

Leaving the Cane River Mine *en route* for the copper lodes the country traversed a highly inclined series of metamorphic sedimen-

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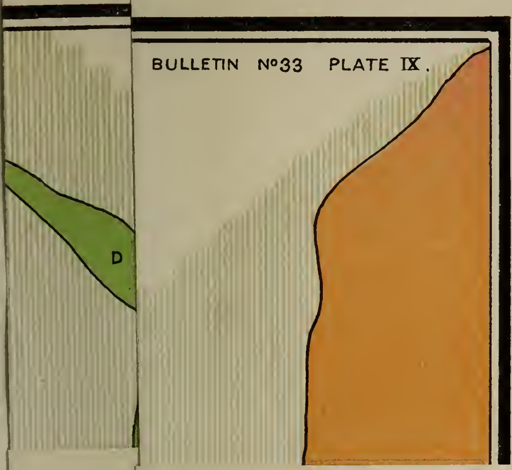
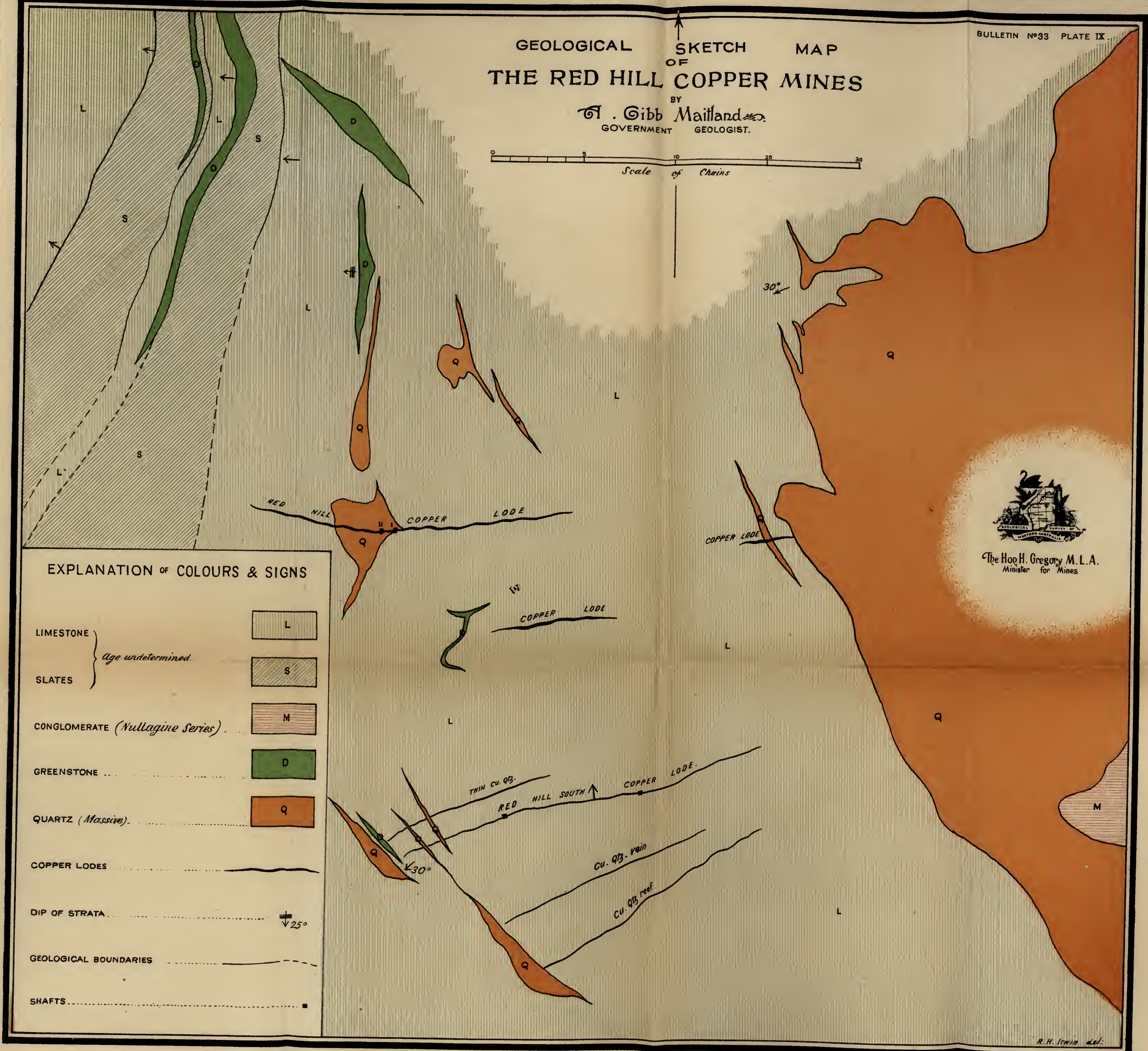
* Lands Department 300 chain Lithograph 96.

BULLETIN Nº33 PLATE IX.





H J Pether, Government Lithographer, Perth, W. A.

tary rocks, e.g., sandstones, quartzites, and limestones, and resting directly upon the upturned edges of these are coarse conglomerates or shingles, which form a broken range of flat-topped hills very well seen to the west of the road.

In the more immediate vicinity of the copper lodes the older beds are well exposed; they consist of limestone [7896] interbedded with quartzites, and micaceous shales. Some miles to the eastward is the escarpment of a long flat-topped range which is geographically part of the Hamersley Range. The horizontally bedded rocks doubtless form part of the same series of strata are exposed therein and to which reference will be found on a later page.

A plan on the scale of five chains per inch was made of the more immediate vicinity of the Copper Lodes and forms Plate IX.

By far the larger portion of the area is made up of beds of siliceous dolomite [7896] dipping westwards at angles of about 30 degrees. These beds rest upon micaceous sandstones or shales. The dolomitic limestone is intersected by large irregular masses or veins of quartz which have a general northerly trend, the largest mass is that which forms the easternmost margin of the area, and forms one of the most conspicuous features in the district. It is not clear whether this mass is not in reality merely a replacement of the limestone by silica. Resting directly on these older rocks are horizontal conglomerates which are merely outliers of the beds in the Hamersley Range. A small corner of one of these is shown on the eastern margin of the geological sketch map. The older or metalliferous series of strata have been invaded by many greenstone dykes all of which are indicated on the map.

The copper lodes, which are quartz reefs, trend generally easterly and are of later date than the large masses of quartz to which reference has already been made. for they traverse them almost at right angles.

Prospecting on the copper lodes has not gone on beyond the most rudimentary stages.

The deposits are said to have been discovered in 1907 by Mr. Wm. Scott, who was the original applicant for the 24-acre lease, known as the Red Hill Copper Mine, M.L. 50, which subsequently received the number M.L. 120H.

Red Hill Copper Mine, M.L. 120H (50).—The lode on this property outcrops for a length of about 1,200 feet and has been exploited by two shallow shafts. The outcrop first makes its appearance on the low ground to the west and rises up the limestone escarpment to a height of about 116 feet at the mouth of No. 2 shaft. No. 2 shaft had been sunk to a depth of 25 feet upon a bunch of copper bearing quartz which at the surface was 18 inches in thickness, but

which gradually petered out. At the foot of the shaft the lode measured about three feet from wall to wall and carried an inch or two of low grade copper and iron-bearing quartz on the hanging wall. No. 1 shaft, distant about 60 feet east from No. 2, had been carried down to a depth of 30 feet on the lode which had been opened out east and west for a distance of about 13 feet. In the eastern drive the lode proved to be about two feet six inches in thickness and not of a very high grade. The lode is a quartz reef containing narrow veins of ores of copper and iron, and in some cases secondary silica; a typical sample of this class of ore [7898] assayed in the Survey Laboratory 4.74 per cent. of copper. A much more ferruginous type of oxidised ore [7897] returned 28.15 per cent. of copper. Exceptionally rich patches yielded [7899] 55.69 per cent. of copper, whilst an average sample of the limonite ore [7900] returned 14.54 per cent. of copper and 28.35 per cent. of iron. The deposit as a whole is small and of very low grade and it is questionable whether in view of its geographical situation and the expenses of cartage, etc., it can be worked with a margin of profit.

According to the information supplied to me by Mr. Kimmorley, the Secretary of the Company, it appears that the cost of transport from the mine to Fremantle amounts to £5 10s. per ton, whilst mining, grading, etc., reaches £3 per ton, or in other words, without smelting charges the expenses amount to at least £8 10s. per ton, so that no ore under 30 per cent. could be expected to be commercially profitable. There appears to be no record of the quantity of ore raised from the property.

Red Hill South Lode.—The Red Hill South Lode, held by Messrs. O'Donnel and Meldrum, had been exploited by a shallow vertical shaft 25 feet deep sunk on a copper-bearing quartz reef.

On the surface near the mouth of the shaft the outcrop is stated to have been two feet six inches in thickness of high grade ore. At the bottom of the shaft and on the eastern side the reef is about two feet in width but between that and the surface it is represented by only a few inches of quartz carrying a little copper ore. The ore [7901] contains large quantities of malachite and chrysocolla. About four tons of picked ore had been bagged and despatched from the mine, and about another four tons were ready for transport. There however does not appear to be any official record of the yield of this property. There are five other similar copper-bearing quartz reefs between the two properties, but none of them have been worked.

Beechworth's Prospecting Area.—A small copper-bearing quartz vein situated some little distance beyond the northern margin of the Geological Sketch Map, Plate IX., has been exploited to a shallow depth by means of a vertical shaft. The lode has an average strike

of north 50 degrees west with an underlie in a western direction. The shaft had been sunk on a thin vein of quartz which at the bottom of the shaft, 20 feet below the surface, was 12 inches in thickness. About one ton of ore is stated to have been obtained from the surface at the mouth of the shaft and at the date of my visit about three tons of ore had been bagged ready for transport. The ore is stated to have been hand-picked and dressed up to about 30 per cent. which seems to be about the lowest grade of ore which, under the conditions prevailing, can be expected to yield any profit.

A little to the south of this prospecting area are a few narrow veins containing ores of iron and copper trending generally north and south. A few bags of ore had been raised from these, but the veins did not appear at all likely to yield any supply of ore.

Niven Copper Lode.—What is known as Niven's Copper Lode lies a little distance from Beechworth's in a westerly direction. The lode is a quartz reef of the usual type with a strike parallel to that of the Red Hill Lode. No work beyond a little desultory prospecting has been done upon it. The deposit is of considerable length and from its appearance it seems possible that as it is opened up a small shoot of high grade ore may be met with. The country rock is dolomitic limestone of the usual type.

Having completed the investigations on the copper lodes we travelled northwards as far as Chalyarn Pool on the Robe River.

On the southern bank of the river at the pool are high cliffs of horizontally-bedded ironstone (? very ferruginous quartzite) about 30 or 40 feet in thickness; these beds form very extensive tablelands of which Mount Darnell forms one. These beds are in all probability outliers of the strata exposed in the Hamersley Range. Knife edge ridges of the older rocks in many places protrude above the general level of the tableland series.

Near Yaraloola Station a discovery of copper-bearing quartz has been made.

Yaraloola Copper Lode, M.L. 113H.—The discovery of the deposit is stated to have been made in 1907 by Mr. Thomas, a kangaroo shooter. The lode is situated about three and a-half miles south-east of Yaraloola Station, upon a low isolated hill on the northern bank of the Robe River, near the pool which is known as Saddleback, on the opposite side of the river to Reserve 9701.* The rise is made up of vertical metamorphic sedimentary rocks which have a general strike of north 35 degrees east. These rocks are traversed by large lenticular veins of quartz, associated with which are copper impregnations and veins. The sketch plan, Fig. 33, indicates the mode of occurrence of the veins.

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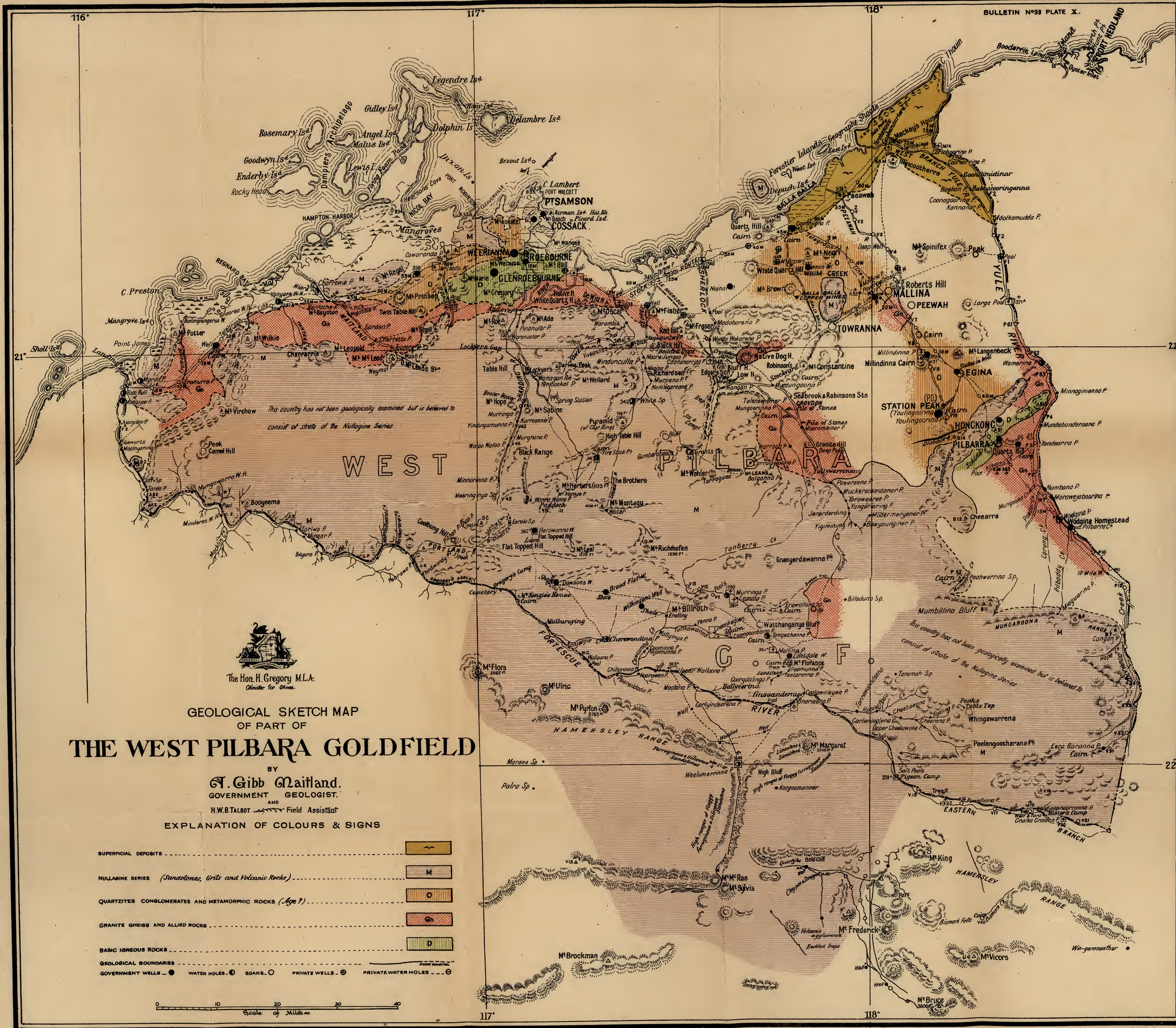
* Lands Department 300 chain Lithograph 96.


SKETCH PLAN
OF
THE YARALOOLA COPPER MINE
ROBE RIVER
0 100 200 300 400
Scale of Feet

Fig. 33.



GEOLOGICAL SKETCH MAP
OF PART OF
THE WEST PILBARA GOLDFIELD
BY
A. Gibb Maitland.
GOVERNMENT GEOLOGIST.
AND
H.W.B. TALBOT Field Assistant
The Hon. H. Gregory M.L.A.
Minister for Mines.
EXPLANATION OF COLOURS & SIGNS
SUPERFICIAL DEPOSITS
NULLAGINE SERIES (Sandstones, Grits and Volcanic Rocks)
M
QUARTZITES CONGLOMERATES AND METAMORPHIC ROCKS (Age?)
O
GRANITE GNEISS AND ALLIED ROCKS
Gn
BASIC IGNEOUS ROCKS
D
GEOLOGICAL BOUNDARIES
GOVERNMENT WELLS
WATER HOLES
SOAKS
PRIVATE WELLS
PRIVATE WATER HOLES
Scale of Miles
0
10
20
30
40
WEST PILBARA
G F
This country has not been geologically examined but is believed to consist of strata of the Nullagine Series
116°
117°
118°
21°
22°
PT SAMSON
COSSACK
ROEBOURNE
GLENROEBOURNE
WEERIANNA
MALLINA
PEEWAH
TOWRANNA
WHIM CREEK
EGINA
STATION PEAK
HONGKONG
PILBARRA
PORT HEDLAND
YULE RIVER
SHERLOCK
FORTESCUE
RIVER
HAMERSLEY RANGE
Mt Bruce
Mt Brockman
Mt Frederick
Mt McRae
Mt Sylvia
Mt King
Mt Vicors
Mt Flora
Mt Ulric
Mt Pyrton
Wodgina Homestead
Dampiers Archipelago
Legendre Isd
Delambre Isd
Rosemary Isd
Enderby Isd
Forestier Islands
Depuch Isd
C. Preston
HAMPTON HARBOR
NICOL BAY

Beyond the fact that copper ore is showing freely as stains and impregnations over a belt about 250 feet wide and at least 400 feet in length no defined lode occurs. The ore is largely green carbonate of copper, red oxide and copper glance. Assays of the ore yielded 18 per cent. of copper together with a little bismuth. No ore had been raised.

THE COUNTRY BETWEEN THE ROBE RIVER AND ROEBOURNE.

(Geological Sketch Map, Plate X.)

Having completed our observations at Yaraloola we followed the main route towards Roebourne, camping for the night at Chingi-narra,* on reaching the Fortescue Telegraph Station on December 5th. No section of the underlying country was noticed *en route*. From the Fortescue River, after getting clear of the wide alluvial flat which flanks either bank, the track passed over the older slates, etc., which were unconformably overlaid by bedded vesicular lavas which occupy the country for some considerable distance. In the watershed of Eramurra Creek granite of the usual type emerges from beneath these volcanic beds; in places the granite is traversed by numerous greenstone dykes. As far as the Aniare River the route traversed a well-grassed level plain bounded on the south by the bold escarpment of the bedded rocks of the Hamersley Range. About a mile to the west of the camp at the well on Reserve 357A on the river is a low ridge rising from amid the plain. The ridge is made up of highly inclined laminated and ferruginous quartzite trending generally east and west, and underlying at a very high angle to the north. Some miles to the south of this hill at the far extremity of the level grassy plain the escarpment of the bedded rocks (lavas?) can be seen and of which Mount Leopold forms one of the most prominent summits. These bedded rocks appear to have a gentle dip to the west and are in all probability arranged in a series of gentle folds. From the Aniare River to Karratha Station on the Maitland River no section of the underlying rocks was seen but in the vicinity of the station are hills of granite (? granitic gneiss) traversed by dykes of greenstone, which make a very prominent feature in the landscape. To the northwards, composing the range of which Mount Regal forms the most prominent summit, there are as seen through a pair of good binoculars a series of bedded rocks which may in all probability be a portion of the strata which make up the plateau of the Hamersley Range.

Between Karratha Station and Reserve 350 the track has been carried over good soil plains, the debris of the beds of the tableland

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* Lands Department 300 chain Lithograph III.

on the south. The plains are underlaid by granite (granitic gneiss?) which is intersected by numerous greenstone dykes the bare black summits of which make most marked features in the landscape.

The face of the tableland to the south shows in the distance the staple formation to be almost horizontally bedded (igneous?) rocks which in one conspicuous instance are intersected by a bold greenstone dyke which cuts clean through the escarpment.

Mount Prinsep along the northern side of the road is of laminated quartzite of the usual type: there are in addition many bold, ice-like quartz reefs, which traverse the country for considerable distances.

THE WEST PILBARA GOLDFIELD.

(With a Geological Sketch Map, Plate X.)

The following general notes were made during a somewhat rapid traverse through the West Pilbara Goldfield, and it was originally intended that an investigation of the country in the more immediate vicinity of the different mining centres should be made on the same lines as that carried out in the Pilbara Goldfield. Circumstances beyond my control, however, rendered this impossible; but this work is being entrusted to Mr. H. P. Woodward, the Assistant Government Geologist.

The West Pilbara Goldfield is situated in latitude 21 deg. south and adjoins the neighbouring Pilbara Goldfield, which has been the subject of three recent reports.*

The field was proclaimed by a *Gazette* notice in November, 1888, and was at that time embraced within the limits of the Pilbara Goldfield; the West Pilbara Goldfield as at present constituted, however, having been proclaimed in October, 1895. The area included within these amended boundaries embrace 9,480 square miles.

The yield of the field, so far as can be deduced from the information supplied to the Mines Department† has been 13,276.32ozs. of fine gold, obtained from the milling of 13,932.25 tons of ore, thus giving an average yield of .95ozs. per ton, also 3,980.32ozs. of alluvial and 220.73ozs. of dollied gold, in addition to 17,191.50 tons of copper ore valued at £194,017.

The following table gives the mineral production of the field up to the close of 1908, as shown by (a) the figures furnished to the Department of Mines, and the data in the archives of H.M. Customs

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* Geological Survey, Bulletins 15, 20, 23, and the reprint in one volume.
† Up to the end of 1908.

house, and the Perth branch of the Royal Mint; it will be noticed there is a difference between the two sets of figures:—

Table showing the Yield of the West Pilbara Goldfield.

I.—Gold Yield.

Year.	Reported to Mines Department.*	Exported and received at Perth Mint.
	fine ozs.	fine ozs.
1889–1897	..	‡
1898	† 1,350·94	1,814·48
1899	1,689·63	1,749·39
1900	779·48	645·61
1901	198·73	435·84
1902	1,910·42	2,822·20
1903	5,100·48	5,493·23
1904	3,427·71	4,320·82
1905	801·14	1,164·92
1906	749·16	755·35
1907	464·08	332·30
1908	1,005·60	1,076·68
Total	17,477·37	20,610·82

* Figures include alluvial, dollied, and specimen gold. † Total prior to 1899, no details given. ‡ Previously shown in the Pilbara Field (*vide* Bull. 15).

II.—Copper Yield.

Year.	Reported to Mines Department.		Exported.	
	Quantity.	Value.	Quantity.	Value.
	tons.	£	tons.	£
1873	..	..	†	..
1891	..	..	263	4,462
1892	..	..	412	6,319
1893	..	..	50	606
1894	..	..	*Nil*	..
1895	..	..	802	12,832
1896	..	..	6	100
1897	..	..	65	731
1898	*7,018·00	55,270	281	3,334
1899	2,555·00	29,478	1,404	31,979
1900	1,605·00	12,139	544	10,696
1901	1,162·00	15,891	1,058	26,464
1902	*Nil*	..	68	1,698
1903	*Nil*	..	4	180
1904	*Nil*	..	50	500
1905	*Nil*	..	*Nil*	..
1906	*Nil*	..	112	3,232
1907	3,365·50	63,548	‡	..
1908	1,486·00	17,691	‡	..
Total	17,191·50	194,017	4,519	102,333

* Total prior to 1899, no details given. † 60 tons said to have been exported, no value stated. ‡ Information not available as the Commonwealth returns do not show the necessary details.

The mining history of the West Pilbara Goldfield seems to have commenced with the discovery of rich copper and lead deposits in the vicinity of Roebourne during 1872, and in the following year 60 tons of copper ore are stated to have been shipped from Cossack. In 1877 rich quartz reefs were discovered near Roebourne which are stated to have yielded over 5ozs. of gold to the ton: five years later, in 1882, Mr. A. McRae picked up a nugget weighing 14ozs. between Cossack and Roebourne. Two promising reefs, the Peawah and Mallina, were discovered in 1888, in addition to several others in the vicinity, showing free gold. The rich alluvial find at Pilbara Creek was made in July of the same year, and in a very short time a large quantity of alluvial gold was obtained. One nugget weighing 127ozs. and several others of from 30 to 40 ounces each were unearthed. In August, 1889, the Nicol River find was made by a Chinaman. The year 1889 saw the erection of two batteries on the field, one by the Broken Reef Company at Pilbara, and the other by the Alfred Argles Company at Mallina. A very rich copper lode was opened about 50 miles east of Roebourne (Whim Creek?) in 1890 and it is stated that in two years over 700 tons of ore were shipped to England; there appear to have been no records of this amount in the published figures of the exports from the district. Since that time, however, mining operations have been practically at a standstill. A marked increase during recent years in the price of the base metals has led to a considerable revival in the district, and the more or less vigorous exploitation of the Whim Well Copper Mine, which up to the end of 1908 turned out 12,735 tons of copper ore valued at £145,703.

The notes embraced by this report deal only very briefly with such of the centres as were passed through when journeying to the Wodgina Tinfield. Detailed observations are being conducted by the Assistant Government Geologist, and will be embodied in a future bulletin, which can only be issued after the field work has been finally completed.

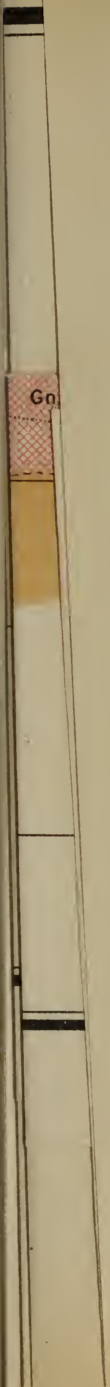
THE ROEBOURNE DISTRICT.

(With a Geological Map, Plate XI.)

The district more immediately surrounding Roebourne was geologically mapped by Mr. H. W. B. Talbot, and the results of his labours are to be found embodied in the map which forms Plate XI. No opportunity, however, presented itself of making any very minute observations in the district, investigations being practically confined to such points as might be expected to throw light upon the possibilities of the district as an ore producer.

Such portion of the district as has been examined was confined almost exclusively to the watershed of the Harding River which rises in what is geographically the Hamersley Range.

In such a hurried traverse as was made through the district very little opportunity presented itself of making any detailed examina-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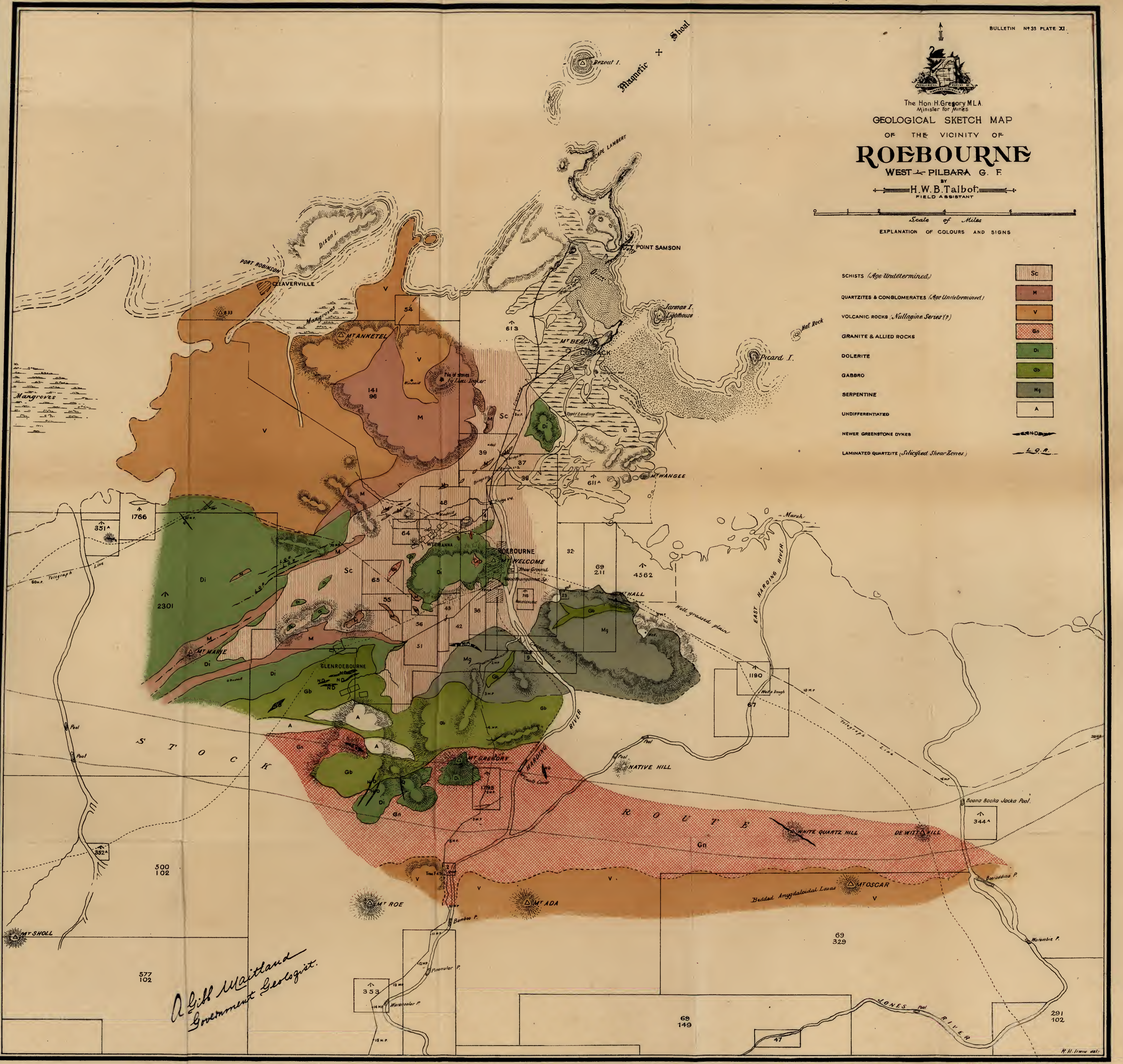


H. J. Pether, Government Lithographer, Perth. W.A.

tion of the geological features of any portion of the neighbourhood of Roebourne.

In its salient features, however, it consists as may be seen by the Geological Sketch Map prepared by my colleague, Mr. H. W. B. Talbot, of a variety of igneous rocks, the mutual relationship of which has yet to be worked out in detail, and a series of sedimentary rocks of, at any rate, two distinct series.

The oldest sedimentary series is that which is developed in the neighbourhood of Weerianna and extends as a more or less continuous formation from Mount Marie to the neighbourhood of Point Sampson. Wherever seen in section these beds are, as a rule, inclined at high angles (60 to 75 degrees) to the south-east; although portions of the larger area, near Mount Anketell, dip in the same direction at about 45 degrees. The strata consist of quartzites and conglomerates some of the former of which are very ferruginous and silicified dolomite [6427] associated with bands of chert.

To the south of the gold mining leases at Weerianna these beds are associated with banded quartz, carbonate, chlorite rock [6402] the origin of which is somewhat obscure. Mr. Thomson in his Petrological Notes draws attention to the fact that in many respects it resembles a sheared igneous rock of the Station Peak type [6481] and also the silicified dolomite [6427] occurring to the north of the Carlow Castle Mine at Glenroebourne. The field relations however seem to point very strongly to the rock being of sedimentary origin.

Many of the beds, more especially in the neighbourhood of Weerianna, are intersected by faults which seem to have no prevailing direction.

The district affords no precise evidence as to the geological age of these sedimentary beds, though it is quite clear that they are of earlier age than those almost horizontal beds which are believed to be of the same age as the Nullagine Series. In their lithological characters these beds resemble in many respects those occurring between Weston's and Uaroo referred to on an earlier page.

As in the case of the old sedimentary rocks of Uaroo, on the Ashburton, those of the neighbourhood of Roebourne are traversed in places by bands of hematite jasper, one of which forms the shore end of the Point Sampson jetty. This latter band, the exact extent of which has not yet been defined, is of importance by virtue of its possible relation to the magnetic shoal to the east of Bezout Island and to which reference is made on a later page.

These ancient sediments are associated with dolerites (diabases) which in places have been transmuted into greenstone schist, as is the case in many of the goldfields of the State, and as is also the case form the matrix of many of the metalliferous deposits in the vicinity. Those, however, in the vicinity of Weerianna are associated with metamorphic rocks of sedimentary origin as are some of those near the Glenroebourne mines.

A very large area of dolerite forms the high ground of which Mount Welcome marks the most prominent summit: this mass is intersected by an intrusive granite. Some miles to the south and to the west of the Harding River at Mount Gregory is another large area of dolerite associated with hornblendic granite which appears also to be of intrusive origin. It is, however, more than likely that this granite is of later date than the granitic gneisses, etc., which outcrop between the Harding and the Jones Rivers, owing to insufficient field work having as yet been carried out in the district all the granites and allied rocks have been designated by one single colour and symbol on the Geological Sketch Map of Roebourne.

The summit of Mount Gregory is invaded by a dyke of gabbro-pegmatite [**6434**,] whilst a fine-grained uralitic-gabbro [**6442**] pierces the serpentine [**6436**] near the southern boundary of Location 42, about three miles north-west of Mount Gregory. The serpentine covers a large extent of country from Mount Hall practically to Glenroebourne. This is pierced by several gabbro dykes which may form a portion of the large mass which extends from the Harding River westward as far as a point about two miles south of Mount Marie.

Some of these igneous rocks are invaded by acidic dykes [**6422**] which have undergone a certain amount of mechanical deformation since their injection and also by a newer series of dolerite dykes.

Amygdaloidal lavas (andesite) [**6440**] occupy a large area of the country in the vicinity of Mount Anketell, and as well as the tableland of which Mount Oscar forms one of the summits. These volcanic beds form part of the Nullagine Series which occurs in such force in the southern portion of the district and fully described in other pages of this report.

A fairly full account of the mines in the vicinity of Roebourne has already been given in a recent report, hence need not be repeated,* more especially as much later observations are being made by Mr. H. P. Woodward.

A point of considerable geological and practical importance is the abnormal variation in the compass off Cossack, better known as "the magnetic shoal off Bezout Island." The existence of this has been known to the masters of vessels trading in and out of Cossack and when passing Bezout Island the precaution is always taken not to steer by the compass.

In consequence of a report made in 1885 by Staff-Commander Coghlan, of H.M.S. "Meda," the matter was fully investigated by Commander Moore of H.M.S. "Penguin" in November of the year 1890. In 1892 this officer gave a full account of the shoal in an address read before the Australasian Association for the Advancement of Science.

From these observations it appeared that the centre of the disturbance lay in about nine fathoms of water at a spot with the beacon

* On the Pilbara and West Pilbara Goldfields, A. Montgomery. Perth: By Authority, 1907.

of Bezout Island bearing S. 78deg. 49min. W. and distant about 2.17 miles; this position has been indicated on the Geological Map, Plate XI. The deflection of the compass amounted to about as much as 55 degrees.

Commander Moore's observations, which are of interest and importance, are given *in extenso*:—

MAGNETIC SHOAL NEAR COSSACK.

The area of magnetic disturbance near Cossack exhibits all the characteristics of red magnetism, as if there was a congestion of the magnetic elements due to the south magnetic hemisphere. It seems appropriate, therefore, to call it a magnetic shoal, and to treat it graphically as if it was an elevation or lump on the bottom of the sea, or area of shoal water, the magnetic soundings being deflections of the compass needle.

Worked out thus, it was found that the magnetic shoal developed the following features:—An area of 4 miles long N.E. and S.W. by 2 miles broad, with a depth of 8 to 9 fathoms at low water spring tide, bottom quartz sand, over which all compasses are deflected one degree or more. Within the above, an area 3 miles long N.E. and S.W. by half a mile to one and a half miles broad, over which compasses are distributed over half a point. Within the above:— (1) A line of maximum easterly repulsion over which the north seeking of the needle is violently repelled to the east, in one place as much as 56 degrees. (2) A line of maximum westerly repulsion, over which the north seeking end of the needle is repelled to the west, but only to the extent of one-half the easterly repulsion. (3) Between these two lines, which are from one to three cables apart, a line of no repulsion 2¼ miles long, over which the needle points to the true north, and the directive force is very small. This is called the "axis," or "line of vanished repulsion." (4) A point on this line about one mile from the south-west end of the magnetic shoal, where the intensity is greatest, which is called the focus. The axis, or line of vanished repulsion, is inclined to the true meridian at an angle of 56 degrees in the neighbourhood of the focus. This angle coincides with the amount of maximum easterly repulsion.

A vessel passing in a straight line across the magnetic shoal at the focus, on a north-westerly course, would find the north seeking end of the needle behave in the following manner:—When about one mile from the focus a slight disturbance would be observed, the north seeking end of the needle being repelled to the east; but this disturbance would not amount to more than half a point until she had run to within 2½ cables of the focus. The needle would then be more and more repelled until 300 feet from the focus, when it would be deflected as much as 56 degrees from the true north. It would then quickly resume its correct position, and over the focus—for a hardly appreciable distance, say 10 feet—would point to the true north. After passing the focus it would be repelled to the west; and at 200 feet from the focus would be deflected as much as 26 degrees from the true north. It would now begin to return again to its correct position, and at 3 cables from the focus on the N.W side would not deviate from the normal more than half a point. At one mile from the focus all signs of disturbance would disappear. Crossing the shoal rectangularly elsewhere than at the focus, similar but less powerful repulsion would be observed. The distance between the largest east and largest west repulsion would be greater.

In a wooden wooden ship or composite vessel like the Penguin, the compasses would act as usual after leaving the shoal. Whether induction would take place or not in an iron vessel is a matter yet to be ascertained. At present there does not seem to be any evidence that there is any danger to navigation, except that a vessel would be set out of

her course if steering by compass when passing over it, more or less, according as to whether she cuts across it at the narrowest point or obliquely.

The focus is in lat. 20deg. 32min. 35sec. S., long. 117deg. 13min. 12sec. E. From it Bezout Island summit bears 578deg. 49min. W., distant 2.17 miles.

The greatest range in the deflection of the compass card was 82 degrees, after applying the deviation for the apparent position of the ship's head; the actual range 88 degrees. The greatest inclination or dip, 81deg. 10min. The greatest intensity or total force found was 18.808 (British units), or nearly double the intensity which, in this locality, is due to the earth considered as a magnet. This is the greatest known intensity generated by an invisible cause. The largest recorded intensity in the world, due to the earth considered as a magnet, is 15.2 B.U., near the south magnetic pole. The statement made by Captain Creak, F.R.S., the Superintendent of Compasses, that the north point of the needle is always repelled from the disturbing cause in the southern magnetic hemisphere is fully confirmed by this investigation.

H.M.S. PENGUIN,
Admiralty Gulf, 28th June, 1891.

Note.—Commander Moore, in forwarding the above to the Admiral, states that "It seems probable that Captain Cook came across an area of disturbance like this when near Magnetic Island, off the Coast of Queensland."*

Two explanations have been brought forward to account for abnormal variations in the magnetic elements,† namely, in the first place "many igneous rocks and notably basalt, contain magnetic oxide of iron, and the deviations of the needle may be explained by the presence of such rocks, either visible upon the surface or concealed beneath it." The second explanation associates the deflection of the needle with "disturbances of the earth currents of electricity produced by irregularities in the geological constitution of the country and especially with geological faults."

A series of experiments show that "igneous rocks which are very feebly magnetic when tested in the laboratory, produce considerable effects upon the magnet when in large masses." As a result of careful investigations extending over five years throughout the United Kingdom, these authors arrive at the conclusion that the theory of the direct action of magnetic rocks agrees best with the observed facts.

Dr. E. Naumann in a paper upon "Magnetism and Earth Structure," expresses the opinion that what he calls "Rock Magnetism," the explanation adopted by Professors Rücker and Thorpe is incapable of producing any very serious effect upon the magnetic curves but lays a greater stress upon the power of "lines of geological disturbance" in the crust of the earth to "deflect electric currents from their direct track and cause irregularities in the magnetic elements.

*Magnetic Shoal near Cossack, Western Australia: Austr. Assoc. Adv. Sci., 1892., pp. 416-418.

† The relation between the Geological Constitution and the Magnetic state of the United Kingdom. A. W. Rücker & T. E. Thorpe. Report of the Brit. Assoc. Adv. Sci. Newcastle, 1889.

Neither of the two above considerations are put forward as the real explanation of the phenomenon noticed off Cossack but merely point out that a mass of evidence has been collected during recent years by which any abnormal variations in the magnetic elements can be accounted for by the geological constitution of the districts in which they occur.

Such abnormal variations in the magnetic elements are by no means uncommon in Western Australia. In 1885 Mr. E. T. Hardman, at that time Government Geologist, drew attention to a deflection in the compass needle of 25 degrees 30 minutes to the east in the vicinity of Mount Angelo, near the Mary River in Kimberley. The range of low hills about four miles long and two wide were made up of dolerite noted for the quantity of magnetite it contained, and even specimens of the rock itself were found to exhibit magnetic polarity.*

A similar occurrence was noticed by Mr. Gibson in the Kimberley District.

Mount Magnet on the Murchison is another locality which owes its name to the deflection of the compass in its vicinity. Mount Magnet is a lofty ridge of laminated jaspery quartzite which rises prominently from the surrounding country; the beds are highly impregnated with oxide of iron and ore in places distinctly magnetic.

Numerous other localities in which these laminated quartzites of the Point Sampson type exist are noted for their action on the magnetic needle even in those cases in which no magnetic oxide of iron can be detected in them.

On the southern coast of the State, at Herald Point, north of Michaelmas Island, Captain Fitzroy noticed that his compasses were so much affected, when set upon the sandy beach, as to vary many degrees from the truth.†

When navigating amongst the islands of the Recherche Archipelago, Flinders observed considerable disturbance of the compass on board his ship, which was probably due to the action of submerged adjacent magnetic rocks. Thus in the neighbourhood of Termination Island (lat. 34deg. 30min. S., long. 121deg. 58min. E.) the variation observed on board when west of the island was five degrees in excess of that observed when east of it.‡

Sufficient however is not known of the geology of the two last districts to enable much to be said as the possible cause of the variations which these two observers noticed.

In the case of Point Sampson, however, it will be noticed that the bar of laminated jaspery quartzite forms the seaward extension of that group which passes through Weerianna.

In the coastal district to the westward between the Nicol and the Fortescue Rivers similar parallel belts have been noticed and

* On the Geology of the Kimberley District, Western Australia, Perth: By Authority 1885, p. 20.
† Voyages of Adventure and Beagle: Capt. Robert Fitzroy, R.N. Vol 11, p. 625.
‡ The Australian Directory (Hydrographic Office), Vol. 1, 1897, p. 102.

described, hence possibly the magnetic shoal may be due to a submarine ridge of similar material. Whatever may be the exact explanation of the cause of this abnormal variation in the magnetic elements off Bezout Island, it is quite clear from the geological constitution that both the conditions described by Drs. Rücker and Thorpe and Professor Naumann prevail on the mainland in the vicinity.

Mount Oscar (Dewitt South) on the western bank of the Jones River is made up of bedded amygdaloidal lavas. The amygdules are principally filled with quartz but occasionally with calcite.

From the summit of Mount Oscar the hills to the south-east were seen to be made up of bedded lavas, the escarpments of which presented a very dark and weathered surface.

BEDDED LAVAS SOUTH OF MOUNT OSCAR.

Fig. 34.

From camp at Booradina Pool, a traverse was made to Black Hill on the eastern bank of the George River. The hill itself consisted of a lofty mass of bare black volcanic rock of the type common to the district. From the summit an excellent view of the surrounding country can be obtained and so far as could be seen the country to the east, south, and west was made up of bedded lavas. The rock forming Black Hill is a fairly coarse-grained greenish white rock, containing felspar, a ferro-magnesian constituent and a

little pyrites. Black Hill may be one of the focii from which the bedded lavas emanated.

These volcanic rocks rest in the valley of the Jones on granite and allied rocks.

Dewitt Hill is made up of tourmaline-gneiss, which is almost vertical.

From camp at Booradina to Goonanarrina Pool (Res. 348A), on the Sherlock River the track followed had been carried over the platform of ancient crystalline rocks which form the bedrock of the district, and upon which the newer beds were laid down.

From Goonanarrina Pool we travelled north-eastwards as far as Mons Cupri, passing *en route* over slates, associated with rocks of igneous affinities and quartz reefs. No opportunity, however, presented itself of making any examination of the mine and its surroundings, owing to the receipt of telegraph instructions requiring me to proceed immediately to Wodgina.

Leaving Mons Cupri we followed the track to Whim Creek, at which slates outcropped. Some distance eastward along the main road to Mallina the track passes up a valley carved out of vesicular lavas of the Nullagine Series, arranged in the form of a synclinal trough. This volcanic tableland covers a fairly large area. It is probable that Depuch Island, which is stated to be of "Columnar Basalt" may be merely a remnant of the northward extension of the plateau.

At Poverty Crossing the underlying slates emerged, which give place to the older granitic rocks, gneisses, etc., some little distance to the south-east of Mallina Well. These granites and gneisses occupy the country at the crossing of Wattle Creek and some distance south-eastward they give place to slates, etc., which make up the staple formation as far as Egina. Grey slates were passed through in the well at Egina.

The hill of which Mount Langenbeck forms a very prominent summit appear to be made up of laminated quartzites of the type which are common in the North-West district.

The old mining centre of **Egina** lies about eight or nine miles north of Hongkong; it is a locality which has been well known as an alluvial field and where very many rich patches have been worked and where a certain amount of gold can always be obtained by dry-blowing. The detrital gold which has hitherto been won was obtained from the gullies and along the water courses on the flats and from the sides and crowns of the numerous low hills in the vicinity. The country rock of the Egina field consists of clayslates; some of it being highly ferruginous and having a weathered outcrop of a very red colour; there are also bands of very indurated slate and schist. The beds, which are either vertical or are inclined at high angles, have a general east and west strike. On the caps of some of the low hills

a little conglomerate is occasionally found; they possibly represent the base of the Nullagine Series which occurs a little distance to the south forming the tableland which divides Egina from Hongkong. Many of the dryblown patches have been worked right up to the conglomerate, which suggests the possibility of the gold having been derived from the basal beds of the series, as at Nullagine and Just-in-time. It is stated on the authority of the late Mr. Becher, at one time Acting Inspector of Mines for the district, that nearly all the alluvial gold was of the uniform shape and size of small melon seeds, and that when many of the slates were carefully split open small particles of ironstone of exactly the same shape were met with. Other portions of the slates showed cavities from which pyrites had evidently leached out. A good deal of the alluvial gold from Egina in the early days is stated to have had particles of ironstone attached to it, a circumstance which suggests the possibility of the original source of the gold being from impregnations in the slates, seeing that there appear to be few if any quartz reefs or veins anywhere. Mr. Becher carefully sampled the slates and obtained no prospects in the dish from any of them. The occurrence of the gold at Egina is certainly of considerable interest and affords ample opportunities for investigation as to its source.

Some distance south-west of Egina is the mining centre of Station Peak (Youlingoorina).

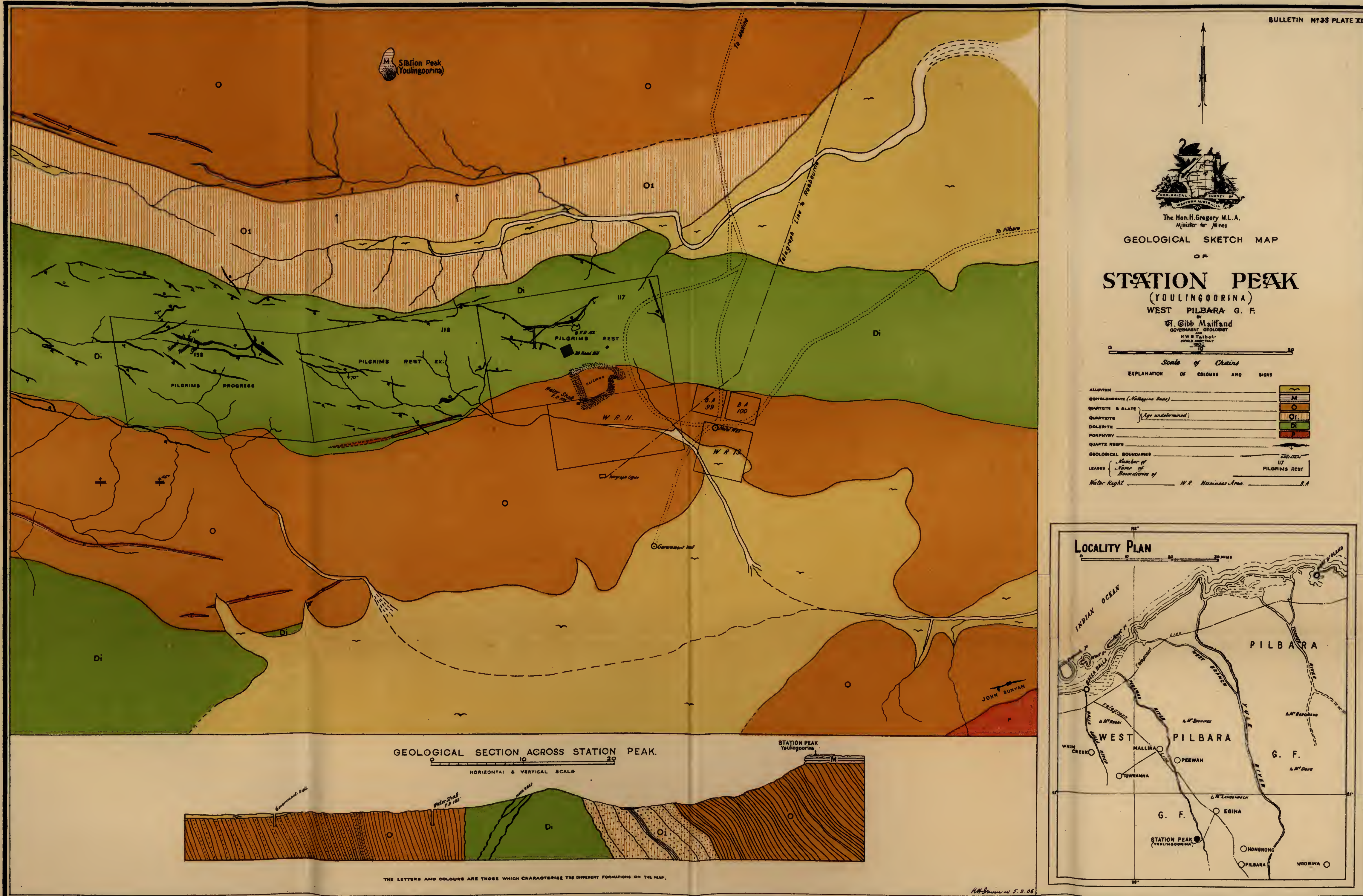
STATION PEAK (YOULINGOORINA).

(With a Geological Sketch Map, Plate XII.)

Station Peak is situated in the watershed of the Peawah River and on the western flank of the valley some little distance from the main watercourse. The locality at which mining operations have been carried on lies due south of Youlingoorina, or Station Peak (Plate XII.), which forms the most important landmark in the vicinity. A fairly lofty ridge traverses the centre of the field due east and west and carries numerous quartz reefs. The ridge is drained by two important tributaries of the Peawah and make very wide alluvial flats. Two of the tributaries as seen on the map gradually lose themselves in the flat, making a lake-like expansion of their channel, which ultimately becomes towards the south-east a well-defined watercourse. The large creek to the north of the Pilgrim's Rest Mine also gradually loses itself on the plain to the eastward.

The mining centre of Station Peak appears to have been discovered in September, 1897, by two prospectors, Messrs. Badgery and Henry, who found about 20ozs. of alluvial gold in one of the gullies. The locality, however, appears to have been abandoned early in October of the same year and it was not until the year 1901 that the first gold mining lease, No. 117, was applied for by Messrs. Albert and David Bull.


BULLETIN N°33 PLATE XII.
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
The Hon. H. Gregory M.L.A.
Minister for Mines
GEOLOGICAL SKETCH MAP
OF
STATION PEAK



H. J. Pether, Government Lithographer, Perth, W.A.

The year 1902 saw the first crushing recorded; the locality continued to be a gold producer—from one mine—until the year 1908, having been responsible for 9,382 fine ounces obtained from the milling of 9,993 tons of quartz.

In its geological structure Station Peak is comparatively simple, consisting of a highly inclined series of sedimentary rocks of the ages of which there is no evidence, invaded by basic and acidic dykes, upon which rest an isolated patch of the Nullagine Series.

The basal beds of the district consist of quartzites, slates, and arkose [6482] the latter of which is fully described in Mr. Thomson's Petrological Notes. These ancient sedimentary beds occupy by far the largest portion of the field and dip northwards at angles from 45 degrees and upwards.

The sediments are traversed by a dyke of quartz-dolerite [6481, 6484] varying from 800 to 1,200 feet in width; this dyke which forms the most important economic feature in the geology of the field is of considerable horizontal extent, though no attempt was made to define it beyond the limits of the geological map (Plate XII.)

Near the south-west corner of the area and about 1,200 feet south of this main dyke is another belt of dolerite [6483] the exact limits of which have not been defined. The slates, etc., near the margin of the mass are very much indurated and point to the dolerite being intrusive.

Another very important feature is the occurrence of a number of porphyry dykes which traverse the whole of the area mapped in the vicinity of the mines in a general east and west direction. These porphyries invade not only the sedimentary rocks but the dolerite dyke also; they do not however appear to rise to the level of and pierce the beds of the Nullagine Series and may in all probability form the apophyses of the large granite mass which lies outside the limits of the area mapped and referred to in other pages of this report.

The main dolerite dyke is of the greatest economic importance owing to its forming the matrix of the auriferous quartz reefs which constitute the *raison d' etre* of the existence of this mining centre.

The dolerite differed very much in texture, varying from medium grain [6483] to a coarse-grained massive green and white rock [6484]. Portions of the dolerite have undergone a certain amount of dynamical alteration resulting in the production of a rock [6481] with a more or less marked foliation but in which the original structure has not been entirely obliterated. These zones of altered rock (crush lines) do not appear to be very wide nor within the area under examination, of inordinate length, and the quartz reefs are almost everywhere confined to them.

The following analyses of the massive and foliated rocks from the same dyke have been made in the Survey Laboratory under the direction of Mr. Simpson:—

—	[6484.]	[6481.]
SiO_2	52·50	49·03
CO_2	1·12	6·03
TiO_2	·78	·36
H_2O combined	2·86	3·82
Na_2O	2·04	·30
K_2O	·61	2·63
MgO	7·22	7·39
CaO	6·73	7·85
MnO	·27	·23
FeO	7·87	6 86
Fe_2O_3	2·75	1·16
Al_2O_3	14·93	14·29
FeS_2 { Fe	·06	04
FeS_2 { S	·07	.05
H_2O hygroscopic	·06	·14
	99·87	100·18
Sp. Gr.	2·89	2·80

[6484] Quartz-hornblende dolerite, Station Peak.

[6481] Calcite-chlorite greenstone, Station Peak.

The results of the analyses show that no specially notable change appears to have taken place in the chemical composition during the process of transmutation.

When examined microscopically as is clearly pointed out by Mr. Thomson the massive rocks [6483, 6484] are uralitised quartz-hornblende dolerite whilst the quasi-foliated variety is best described as a calcite-chlorite greenstone, the alteration having hardly proceeded far enough to produce calcareous chlorite schists.

The Nullagine Beds are represented by an outlier on the summit of Youlingoorina Peak, where they are seen to rest with a violent unconformity upon the upturned edges of the beds beneath.

The beds are composed of a boulder conglomerate lying practically horizontally and forms an outlying remnant of that extensive tableland which divides the waters of the Yule and the Peawah Rivers and described on a later page of this report.

The conglomerate on the Peak is traversed on its southern side by a fault (? joint plane) dipping at an angle of about 40 degres in a direction of south 25 degrees west.

A few miles to the southwards of Station Peak and beyond the limits of the area mapped is a much larger tableland in which the

Fig. 35.
UNCONFORMITY AT STATION PEAK.

unconformity of the Nullagine Beds and the older slates is also seen and is indicated in the photograph which forms Fig. 36.

The quartz reefs of Station Peak as may be seen by an inspection of the geological map have a more or less parallelism which is

roughly approximate to the general trend of the strike of the dolerite dyke, in which the majority of them lie. There are, however, one or

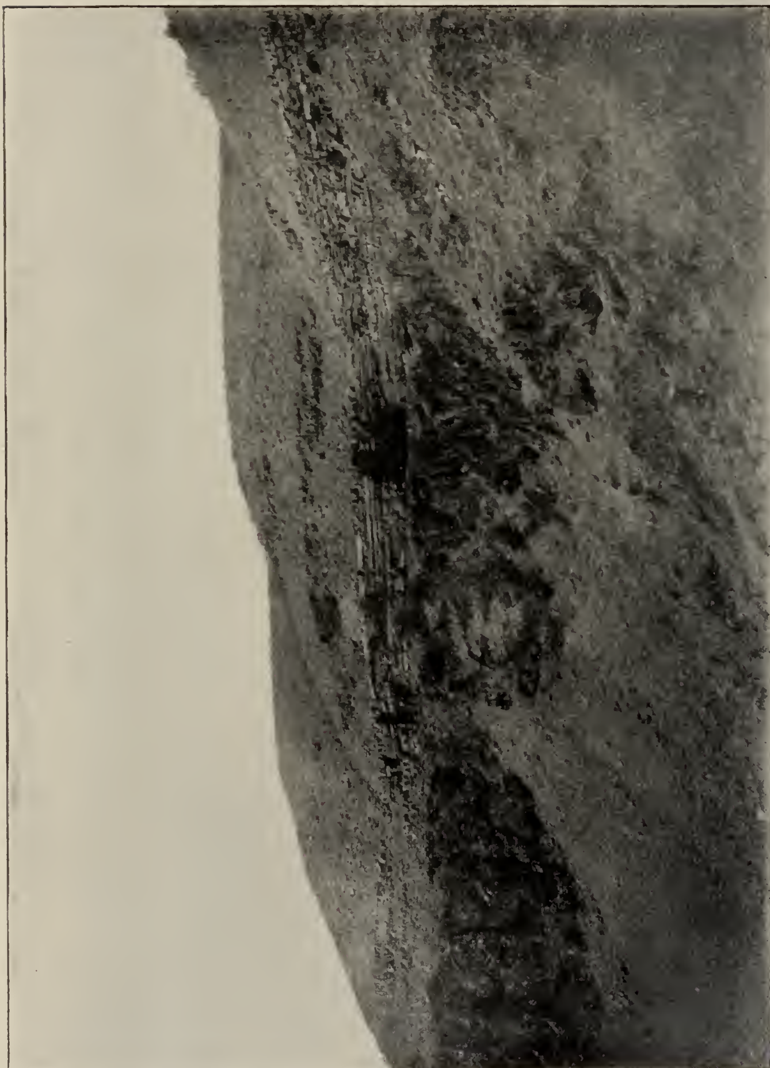


Fig. 36.
UNCONFORMITY BETWEEN NULLAGINE BEDS AND OLDER SLATES.

two which have a trend differing from that of the majority, but they are not very numerous. So far the quartz reefs underlie to the south.

In a general way the length of the reefs may be said to be fairly considerable for as a rule the length is determined by the extent of a

more or less continuous fracture. It is especially the case with what may be called the Main Pilgrim's Rest reef, which as the map shows fills an irregular fissure which has a length of about 4,000 feet. It is, however, only at its eastern extremity where it has been worked in that portion which is contained within the boundaries of G.M.L. 117, Pilgrim's Rest.

The thickness of the reefs varies from an eighth of an inch up to as much as 20 feet such depending primarily upon the dimensions and shape of the fissure in which the quartz is contained.

As a whole the quartz is of a bluish white colour, sometimes discoloured with oxide of iron; the stone contains in many places copper as well as more or less arsenical pyrites.

The quartz reefs are not everywhere confined to the dolerite but cases occur in which they traverse the sedimentary beds and intersect the porphyry dykes.

The district affords no precise evidence as to the geological age of the quartz reefs though the fact that some traverse the porphyry dykes indicates quite clearly that the fissuring and subsequent mineralisation took place at a date subsequent to the injection of the porphyry. So far these acidic dykes have not been found to rise to the level of and pierce the overlying Nullagine Series, hence it is clear that whatever may be the exact position of that series in the geological time scale the age of the Station Peak reefs is pre-Nullagine.

The intrusion of the great mass of granite previously alluded to and of which the porphyries probably form the apophyses seem to have been the culminating effect of intense earth movements which would doubtless tend to produce fractures and fissures which subsequently became mineralised, thus forming the lodes of the district.

Station Peak however is essentially a one-mine township which depends for its prosperity upon the success of the Pilgrim's Rest Gold Mine which has yielded up to the end of 1908, 9,382 ounces of fine gold.

Pilgrim's Rest Mine, G.M.Ls. 117, 118.—These two gold-mining leases were applied for in September, 1901, by Messrs. Albert and David Bull.

Owing to the absence of mine plans any adequate description of the ore deposit worked in the mine cannot be given in a manner which is readily intelligible.

Practically there are two reefs on the mine, known respectively as the No. 1 and the Footwall reefs; the two are connected by a cross vein, the No. 2 or Hangingwall reef. A third small spur vein (No. 3) branches off from the footwall reef, but does not appear, however, to be of much importance. The position and relationship

of the various reefs is shown in Fig. 37 which includes the whole of the lease No. 117.

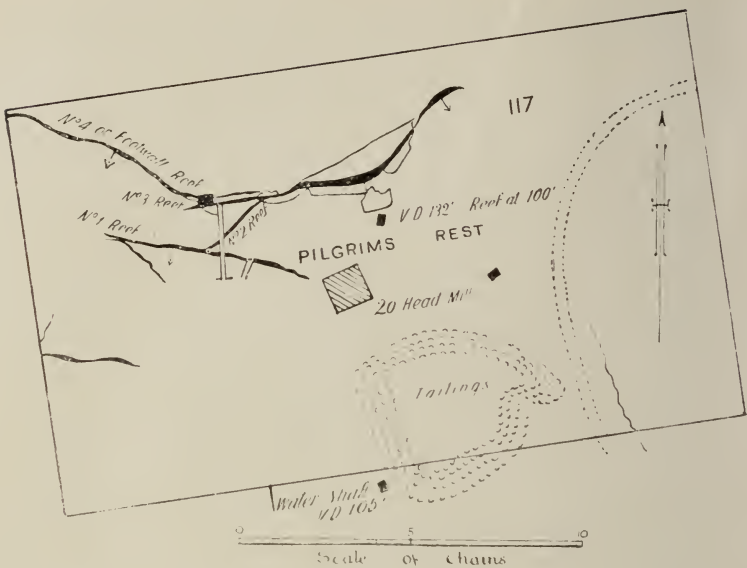


Fig. 37.

Sections in the mine show that a certain amount of faulting has gone on since the formation of the reef and that some portions of the main or footwall reef have been subjected to a considerable amount of lateral pressure, rendering it more or less fissile, shattered and in places broken.

The principal work on the mine has been carried out by means of a long opencut in the footwall reef which underlies south at an angle of about 40 degrees. The workings in the opencut are about 500 feet in length and the reef has been worked down to the level of the tunnel by which the ore is conveyed to the 20-head mill adjacent to the eastern extremity of the No. 1 reef.

So far as could be ascertained by inspection it appeared that the main reef averaged about 10 feet in thickness. No. 2 or the hanging wall reef underlies at about 60 degrees to the south and was intersected in the main shaft 132 feet in depth at a point about 100 feet below the surface, where it proved to be about eight feet in thickness. About 50 feet of cross-cutting has been carried out on it in this shaft which however was inaccessible to me.

The eastern end of No. 1 reef has been opencut for a short distance and a little ore taken out, but of what grade there appears to be no record.

To the south of the large tailings heap is a vertical water shaft 105 feet in depth sunk through the sedimentary rocks, but it was inaccessible at the time the locality was visited. It is stated that about 200 feet of crosscutting has been done in the water shaft.

The following table gives the yield of the mine in fine ounces:—

Table showing the Yield of the Pilgrim's Rest Reef.

Year.	Name and Number of Lease.	Ore crushed.	Gold therefrom.	Rate per ton.
		tons.	fine ozs.	fine ozs.
1902 ..	Pilgrim's Rest G.M.Ls. 117, 118	780·00	930·21	1·20
1903 ..	Do. do. ..	4,673·00	4,542·36	·97
1904 ..	Do. do. ..	3,546·00	3.127·09	·88
1905 ..	Do. do. ..	235·00	257·41	1·09
1906 ..	Do. do. ..	364·00	294·66	·80
1906 ..	Pilgrim's Rest G.M.L. 117..	150·00	74·15	·49
1907 ..	Do. do. ..	245·00	134·12	·54
1908 ..	Do. do. ..	..	22·00	..
	Total	**9,993·00**	9,382·00	·93

Pilgrim's Progress, G.M.L. 133.—This lease adjoins the Pilgrim's Rest group on the west and was originally applied for in 1904 by Mr. C. A. Bull.

The northern portion of the lease is traversed by a very pronounced quartz reef of some considerable thickness upon which a little work had been done.

An inaccessible shaft had been put down to a depth of 65 feet upon the reef which makes a prominent outcrop on the southern slopes of the main ridge, which traverses the district and about 200 feet of crosscutting is stated to have been carried out. The shaft underlies at an angle of about 60 to 70 degrees southwards and has been sunk about 15 feet west from the eastern end of an opencut about 37 feet long and which exposes the reef throughout its whole length.

Forty-eight feet west from the shaft a tunnel has been driven 20 feet north and exposes 11 feet 9 inches of quartz underlying at 55 degrees to the south. The country rock is a decomposed cleaved greenstone (dolerite).

A second tunnel, 20 feet in length, has been put in at a point 72 feet west of that previously described and exposes 8 feet 4 inches of quartz of the usual type. As seen in the cutting the hanging wall country of the reef is traversed by eight or nine quartz veins of about an inch each in thickness. No other work has been done upon the reef.

About 31 feet south is the outcrop of another parallel reef which does not appear to have been worked but which is connected with what may be called the main reef, near its eastern extremity as indicated on the geological map (Plate XII.) As this smaller parallel reef is almost vertical it is quite possible that the two veins may coalesce at some little distance below the surface.

About 200 tons of ore are stated to have been raised from the mine but there does not appear to be a record of any of it having been crushed.

John Bunyan.—A well-defined quartz reef, known as the John Bunyan, lies some distance to the south-east of the Pilgrim's Rest mine, and just near the south-east corner of the map, but very little work had been done upon it. The reef is in the sedimentary rocks, and is adjacent to a mass of porphyry, the boundaries of which have not been defined, lying as they do beyond the limits of the area under examination.

HONGKONG AND PILBARA.

The Nullagine Series is well exposed on the tableland which separates the waters of Friendly Creek from those of the Peawah River. The beds of the tableland consist of almost horizontal sandstones, grits, fine conglomerates and vesicular lavas, which continue almost as far as the Government well at Hongkong. From beneath these crop out those metamorphic rocks which form the matrices of the auriferous deposits of Hongkong and Pilbara.

The **Hongkong District** lies about six miles north of Pilbara, and appears to have been first opened up about the year 1895. The country rock of the district consists of schists of the prevailing type intersected by small, rich, though not very consistent quartz veins. There does not, however, appear to have been any very extensive work done in the district. The schists are overlaid by the sedimentary and volcanic rocks of the Nullagine Series, which form the almost horizontal tableland referred to as separating Hongkong from Station Peak. It does not appear, however, that any serious effort has been made to prospect the basal beds of the Nullagine Series in the district. Timber for mining purposes is scarce in the vicinity, but there is a good supply of water in the Government well, and in all probability further supplies could be obtained by sinking in

judiciously selected localities. Neither mining nor prospecting of any kind whatever was being carried out at the time I passed through this portion of the West Pilbara Field, hence no examination of the workings was possible.

About three or four miles south-south-east of Hongkong lies the old mining centre of Pilbara which appears to have been discovered in July, 1888, and to have been one of the first alluvial fields in the North-West. **Pilbara** is situated about 10 miles west of the Yule River, along the western margin of the mass of intrusive granite which occupies such a large area of country in this portion of the State. The country rock of Pilbara, however, consists of metamorphic quartzites and schists, some of which appear to have affinities with rocks of igneous origin. These beds are also associated with conspicuous bands of laminated quartzite (?) which in all probability form the extension of that belt, which crosses the Yule River near Minnaginienna Pool.* A little distance to the west of Pilbara the schists, etc., are unconformably overlaid by the almost horizontal strata of the Nullagine Series, which occurs in great force in this locality. The schists and allied rocks are traversed by quartz reefs of the irregular type and here and there by acidic dykes which form the apophyses of the mass of granite previously alluded to. The gullies and flats have been very extensively worked for the detrital gold they contained. The gullies have yielded some thousands of ounces, chiefly slugs, nuggets and coarse gold, much of which in all probability has never been officially reported to the Government. It is stated that some of the finest specimen stone found anywhere in the North-West was taken from the quartz veins of Pilbara. The occurrences of veins of intrusive granite in the district should encourage the search for tin in the vicinity, as the prevailing geological conditions are in every way identical with those of the tin-bearing centres of the adjoining goldfield of Pilbara. Firewood and timber for mining purposes is scarce in the neighbourhood but water in abundance can be obtained at favourable localities at no very great depth. There are no crushing facilities in the district. The Pilbara centre is one which has always enjoyed a good reputation amongst prospectors in that many of them return there after prospecting in the outside districts, and claim to be able to more than make a reasonable livelihood. Owing to the condition of pretty well all the mines, I was unable to ascertain from personal observation anything of either the extent of the workings or even of the behaviour of the ore deposits underground. So far as my own personal observations on the surface could be carried, the quartz reefs and veins appeared to be of that type which characterised most of the auriferous deposits of the North-West and to carry short but rich shoots of gold, the exploita-

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* Lands Department 300 chain Lithograph 110; also Geological Sketch Map of the Pilbara Goldfield, Bull. 23.

tion of which seems best suited to the operations of small co-operative syndicates.

A TRAVERSE FROM CROYDON TO THE HAMERSLEY RANGE.

(With a Geological Section, Plate XIII.)

In order to obtain a fairly comprehensive idea of the structural relationships of the various formations exposed, but more especially of the important Nullagine Series, it was decided to make a rapid traverse southwards into the heart of the Hamersley Range, and for this purpose the route from the Sherlock River, via Croydon to Mount McRae, was selected as being most likely to afford the greatest amount of information in the shortest time.

The lower reaches of the Sherlock River expose granite, gneiss, and crystalline schists of various types. There are distinct traces of a double foliation in the gneiss, which is stated to be particularly well seen in the bed of the Sherlock River, where it is crossed by the road to Mallina. The older and coarser banding has a north and south strike, and at right angles to this are zones of secondary and much finer foliation, within which it has the character of a mylonite or a fine quartz schist perfectly distinct from the original rock.*

In the vicinity of Sherlock Station a very green-coloured rock occurs, fuchsite rock, which consists almost entirely of small scales of the characteristic chrome mica—fuchsite—it doubtless occurs in association with the crystalline schists.

Messrs. Clarke's antimony and gold mines occur also in these schists. The mine is stated to be situated near the Sherlock River where it is crossed by the road from Roebourne to Croydon, and eight miles from Sherlock Station.†

These older crystalline schists and gneisses form the platform upon which the newer beds were laid down. The unconformity is exposed in the Sherlock River in the vicinity of Goonanarrina Pool, Reserve 346, where on the western bank of the river the following section is visible:—

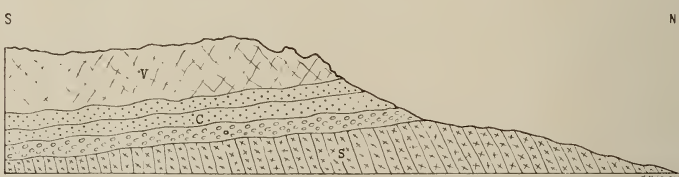
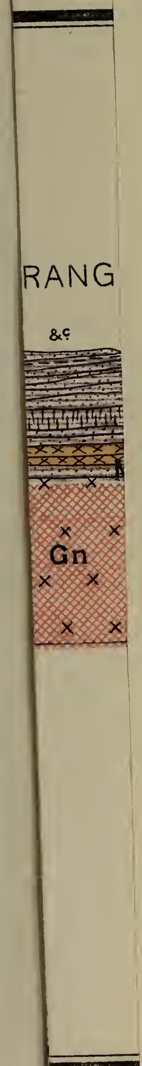


Fig. 38.

* The Geological Features of the Coast of Western Australia: H. M. Cadell. Trans. Geol. Soc., Edin., 1896.

† The Pilbara and West Pilbara Goldfields. A Montgomery. Perth: By Authority, 1907, p. 31.


RANG
&c
Gn

The Hon. H. Gregory M.L.A.
Minister for Mines

GENERALISED SECTION FROM THE COAST TO THE HAMERSLEY RANGE.

Gs ........UNDIFFERENTIATED CRYSTALLINE SCHISTS AND GNEISS.

Gn ....GRANITE.

M ....SANDSTONE, GRIT, CONGLOMERATE AND LIMESTONE *(Nullagine Series)*

V ....LAVAS *(Nullagine Series)*

Va ....AGGLOMERATE.

H. J. Pether, Government Lithographer, Perth, W. A.

An excellent section of the basal conglomerate of the Nullagine series is visible in the bed of the river below the pool, a photograph of which forms Figure 38.

BASAL CONGLOMERATE, NULLAGINE SERIES, COONANARRINA POOL, SHERLOCK RIVER.

Fig. 39.

Following up the river as far as Kangan Pool, there are many sections to be seen exposing sandstones and conglomerates lying beneath the volcanic series; the whole dipping at angles of from five to 10 degrees to the west and south-west. At Kangan Pool the conglomerate dips at 10 degrees to the west.

Camping for the night at Kangan Pool opportunity was taken to examine as much in the vicinity as was found possible and for this purpose a conspicuous hill, rising to a height of about 530 feet above the pool, was selected as being likely to afford a good deal of information.

The position of the hill was fixed by the following bearings taken from its summit:—Kangan Pool, 34deg. 30min. and Pyramid Hill 255deg. An excellent view of the surrounding country was obtained from the summit and it was noticed that between it and Pyramid Hill the country consisted of volcanic rocks resting upon the quartzites, sandstones, and conglomerates, which dip at a low

angle to the westward. The river was followed round as far as Croydon Station. At the homestead:—

"There is an excellent exposure of conglomerates, grits, and schists probably of the Archean 'Mosquito Series.' The beds strike nearly north and south and dip nearly vertically and are strongly jointed and often traversed by quartz veins in which a little gold is stated to have been found. The grits seem to be mainly composed of disintegrated granitic material and afford fairly good building stone, made use of in the erection of the homestead buildings."*

It is not at all improbable that the sedimentary beds of Croydon Station form part of the same series as those exposed at Station Peak; no opportunity however presented itself of examining the Croydon beds in any detail.

At Croydon granite makes its appearance and occupies the country in the vicinity of the route for a distance of about fifteen miles to the south as far as an outstation. Some of the granite is of a very coarse grain and contains very large crystals of felspar. In the vicinity of the outstation near Powereena Pool the granite gives place to bedded lavas of the Nullagine Series.

Camp was pitched at the crossing of Nunyerri Creek (not shown on any published map) at an altitude of 520 feet above Croydon Station. Sections in the vicinity of the camp showed the staple formation to be bedded lavas of the usual type; with about a mile to the east, a very precipitous escarpment of what looked very like one of those "laminated quartzites" which form such a conspicuous feature elsewhere. This band subtended an angle of from 66 to 196 degrees, and overlying it could be seen almost horizontal beds of sandstone, etc., of the Nullagine Series.

Following up the Creek for some miles the bedded lavas gave place to granite and allied rocks which occupied the country for nearly 10 miles. It appears from the general contour of the country that the old granitic floor upon which these beds are laid down had an unusually uneven surface. A little to the west of the route followed was the escarpment of the beds of the Nullagine Series.

Still travelling in a general southerly direction the granitic rocks above-mentioned disappear beneath beds of grit and fine conglomerate, overlaid by bedded lavas dipping at a low angle to the south which form a very extensive tableland covered with good dark soil. Camp was pitched at Lonsdale Well, Reserve 5514. The escarpment of this lava is stated on the authority of Mr. Church of the Mt. Florence Station to continue for nearly one hundred miles parallel to the face of the Hamersley Range proper, which latter however merely forms the highest portion of the plateau.

Leaving camp at Lonsdale Well our route lay southwards through a rocky gorge, where bedded lavas are seen dipping south, which are in turn covered by sandstones. The track down to the

* The Pilbara and West Pilbara Goldfields. A. Montgomery. Perth: By Authority, 1907, p. 46.

Fortescue River from the Rocky Gorge has been carried over one of the sandstone beds which rests directly on the lavas.

The Fortescue River flows north-westwards in a wide longitudinal valley carved out of the beds of the range.

Camp was pitched at a windmill to the south of the river and about four or five miles due north of the face of the range at an altitude of about 2,060 feet above sea level.

From camp an effort was made to reach Mount Margaret on foot. A sharp walk of about an hour's duration brought us to the foot of the range at an altitude of about 180 feet above the windmill. At the foot of the range, resting upon the sandstone, is a considerable thickness of thinly bedded limestones which can be seen forming conspicuous escarpments in the face of the range. So far as could be determined these limestones are unfossiliferous; they are 320 feet thick and contain layers and nodules of chert. The limestones have a peculiar characteristic weathered surface not unlike an elephant's hide.

An excellent view of Mount Margaret was obtained from this point and forms Fig. 40.

MT. MARGARET, LOOKING EAST, HAMERSLEY RANGE.

Fig. 40.

To the summit of the tableland were very fine-grained ferruginous flaggy sandstones with some very silicious bands [6445] and also some banded ironstones [6446]. A sample [6445] yielded on

assay 28.12 per cent. of iron. The rocks, which are described in detail in the Petrological Notes by Mr. Thomson, bear a marked resemblance to some of those banded ironstones which form such a conspicuous feature in the Eastern Goldfields. The beds in this section are horizontal and of course lie on a much higher horizon than the limestones previously alluded to. A very long steep-sided cañon 300 feet in depth has been excavated by one of the tributaries of the Fortescue and flows at the foot of Mt. Margaret through practically horizontally bedded sandstones, etc. Fig. 41.

VIEW IN CAÑON IN HAMERSLEY RANGE.
Fig. 41.

Leaving camp at the windmill our route lay via the Hamersley Station woolshed, situated on one of the tributaries of Weelumerrina Creek; between the woolshed and Weelumerrina Spring, Reserve 1544, the limestones mentioned above were crossed and are covered by banded siliceous ironstones.

The country to the west of the spring is made up of high hills rising to a height of about 840 feet.

These hills consist from base to summit of beds of siliceous ironstone with a few kaolinic bands [6448] which may possibly represent submarine volcanic ashes. These beds dip south at angles varying from five to ten degrees. A sample of the banded iron ore yielded 37.40 per cent. of iron. The very siliceous iron ores bear a marked lithological resemblance to those banded iron ores which make such a conspicuous feature in the geology of most of the goldfields of the State and suggest a common origin for the two.

To the east of the spring a broad anticlinal fold brings the limestones to the surface; the axis of this fold can be traced across

GENERAL VIEW IN THE HAMERSLEY RANGE.
Fig. 42.

country for at least 10 or 15 miles along a bearing of 277 degrees, and the beds dip at low angles north and south respectively. These limestones are in very thin bands of about a foot in thickness.

The following is an analysis of a specimen of this limestone [**6449**] collected from the neighbourhood of Weelumerrina Spring, Hamersley Range:—

$Si\,O_2$	1·69
$C\,O_2$	42·65
$P_2\,O_5$	·02
$S\,O_3$	Slight trace
Cl	*Nil*
$H_2\,O$ combined	·14
$Na_2\,O$	·35
$K_2\,O$	*Nil*
$Mg\,O$	·38
$Ca\,O$	53·24
$Mn\,O$	·64
$Fe\,O$	·88
$Fe_2\,O_3$	·57
$Cl_2\,O_3$	·17
$Fe\,S_2$	*Nil*
Organic matter	trace
$H_2\,O$ hygroscopic	·04
	100·77
Specific Gravity	2·73

One of the highest hills to the south of the camp at Weelumerrina, and 1,200 feet above it, exposed bed upon bed of ferruginous sandstones, with near the summit certain very jaspideous layers very like some of those at Marble Bar, Lalla Rookh, Mt. Magnet, etc. Some of the bands contain very silicеous and cherty layers.

Leaving Weelumerrina Spring and following the creek right through the Hamersley Range and at a point just about along the northern boundary of 130/96, where it is crossed by the main road, the laminated quartzites which are disposed in a series of gently undulating folds end, and the rugged ranges give place to a very extensive open plain, which forms the divide between the headwaters of the Fortescue and the Ashburton. The Hamersley Head Station lies at the foot of Mount McRea at an altitude estimated to be, by aneroid measurement, 2,500 feet above sea level.

Mounts Sylvia and McRae are made up of beds of quartzite of the prevailing type.

The plains which are covered with a considerable thickness of good black soil are underlaid by the volcanic rocks which are interbedded with the sandstones and quartzites.

Some miles to the south-west of the Hamersley Station lies a conspicuous hill 750 feet, by aneroid, above the homestead, which formed the summit of a long ridge of volcanic agglomerate [**6450**]. This doubtless formed one of the focii from which the bedded lavas of the range emanated.

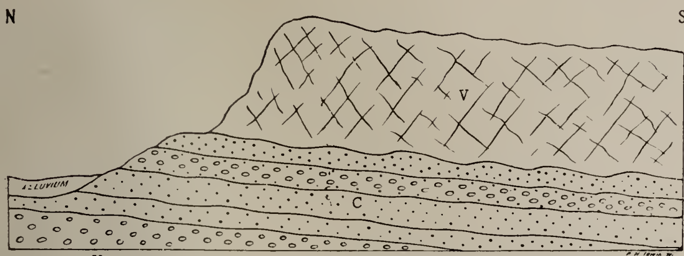
Having completed the hurried examination of the vicinity of Mount McRae, the return journey was made over the same route as far as the woolshed. Leaving the woolshed the track we followed skirted the foot of the Hamersley Range in a general north-westerly direction; at one spot near the foot of the range the limestones previously alluded to again make their appearance but do not occupy the country for any distance along the route followed.

Our route lay across the Fortescue River, at Upper Walloona Pool, Res. 363A, and a halt for the night was made at Res. 3305, Tunkawanna Creek, near the police camp. From the police camp exigencies of travel led us to follow the road via Wilkerson's Well, Res. 5511. The material lying round the mouth of the well showed that it had been sunk through nothing else but white and black shale. Eight miles further west was Broad Flat Well, Res. 5510, which had also been carried down in shales of the usual type; some of the shaly beds carried large quantities of pyrites.

Leaving the Broad Flat, Dawson's Well, Res. 5509, was passed in about eight miles, and judging from the débris lying round the mouth it had also been sunk through shale of the prevailing type. From beneath the shales sandstones emerged, about four miles northwest from the well, and at the junction of the road to Millstream Station, the lavas underlying make their appearance and occupy the whole of the country as far as Barowanna Well, Res. 382A. From this well the track gradually descends into the valley of the George

over alternations of lavas and sandstones which dip southwards at angles of about five degrees. Mount Herbert which lies to the south of the track is of sandstone and lavas.

The face of the tableland near the 46-mile post shows the section depicted in Fig. 43.



V LAVA C GRITS AND FINE CONGLOMERATE

SECTION NEAR 46 MILE POST TABLELAND ROAD HAMERSLEY RANGE

Fig. 43.

Descending from the tableland into the valley of the George a halt for the night was made at Firestick Point, Res. 341A, just below the outcrop of the lavas which form a fairly conspicuous escarpment on either side of the valley. Travelling down the valley, Pyramid Hill was passed and was seen to consist of two series of rocks; an upper of what looked in the distance like the lavas of the tableland of which it is an outlier and a lower sandstones, grits, etc., of the type which form the bed of the valley. From this point the route via Pyramid Station was followed and thence eastward to Goonanarrina Pool, from which point the traverse to the Hamersley Range was commenced.

By means of this traverse a fairly complete section of the beds of the Nullagine Series was obtained and coupled with the information obtained on the divide between the Lyons and the Ashburton adds considerably to our knowledge of this most important geological formation, though a good deal yet remains to be done before anything more than the salient features can be grasped. The whole formation, which covers such an extensive area in this portion of the State, is evidently in the Hamersley Range of considerable thickness and the soil derived from the disintegration of the lava beds produces excellent pastoral country, but is so far as is known destitute of metalliferous deposits other than the iron ores previously alluded to.

GENERAL SUMMARY OF MINERAL RESOURCES.

The country traversed and described in this report is shown in the Sketch Map which forms the frontispiece and covering as it does so many degrees in latitude, comprises a great diversity of geological

formations, though in its broad outlines its geological structure appears to be fairly simple.

It is drained by the Gascoyne, Minilya, Ashburton, Fortescue, and several minor rivers, which take their rise in the high plateau of the interior, which lies outside the limits of the country dealt with in this report.

By far the larger area is made up of beds of the Nullagine and Bangemall Series, which constitute the high plateau breached by the Ashburton River. The escarpment of the beds composing this series form imposing features in the landscape and especially in the Hamersley Range rise as series of terraces at various elevations one above the other. This range contains what is believed to be one of the highest summits in Western Australia, viz., Mt. Bruce, which rises to an altitude of over 4,000 feet above sea level.

The area between the Yannerie and Fortescue Rivers is of considerable importance, both economically and geologically, though until quite recently very little definite information was available as to its resources. The relatively high prices of copper, lead, and other base metals prevailing during the last few years has led to a certain amount of active mining and prospecting in isolated portions of the district, notably between the Ashburton and the Fortescue Rivers, but up to the present time no very valuable deposits have been opened up. The district, however, is worthy of systematic prospecting for it is of a highly metalliferous character and there is every reason to believe that further discoveries will be made as time goes on.

Gold.—The district embraced by this report contains several gold-bearing areas, scattered over widely separated localities. So far as observations have been carried up to the present these auriferous deposits are of diverse types, and possibly of different geological ages, but they everywhere conform to the dominant structural features of the district.

At Bangemall, on the Lyons River, the productive auriferous area lies between two conspicuous bands of micaceous quartzschist forming the legs of a denuded anticlinal fold which has a decided pitch to the south-east. These two bands trend across country for considerable distances and about 12 miles north-west from Bangemall are also associated with auriferous quartz veins. The most important feature at Bangemall is the saddle-reef nature of the quartz veins. Up to the present time though no very valuable reefs have been laid bare, it is possible that as in the case in Bendigo, Victoria, other similar saddle reefs (which may prove productive) exist beneath those indicated in the geological map.

The Ashburton River cuts through the lofty tableland, which extends from Coorabooka to the Hamersley Range and exposes a few auriferous deposits which exist in the older formations beneath the beds of the Bangemall-Nullagine Series. The extent of the pos-

sible auriferous country in this portion of the district is defined by the escarpment of the newer series on both sides of the valley; hence it is an important problem in economic geology to delineate the boundary between the two formations, more especially as on the flanks of the Ashburton Valley there is a possibility of auriferous conglomerates of the Nullagine and Just-in-Time type occurring at the base of the upper series.

It is not, however, until the northern margin of the Nullagine Series is reached in the valley of the Yule, the Sherlock, etc., that other auriferous deposits are met with. Here are to be found the old mining centres of Mallina, Peewah, Egina, Hong Kong, Pilbara, Towranna, Weerianna, Station Peak, and the Lower Nicol.

The neighbourhood of Egina has been noted for its rich patches of alluvial gold, which there seems sound geological reasons for believing to have been derived from the disintegration of the basal beds of the Nullagine Series which occurs in great force in this neighbourhood and affords further proof of the possibilities of this formation becoming a gold producer in other portions than Nullagine and Just-in-Time.

The auriferous deposits of Station Peak are contained in a dyke of quartz dolerite which traverses along the strike of a highly inclined series of sedimentary rocks. A certain amount of foliation has been induced in the dolerite and the auriferous quartz reefs are practically confined to these zones of altered rocks though cases occur in which they traverse these sedimentary beds, but they do not appear to be highly auriferous. It is desirable that this belt of dolerite should be traversed across country in order that the auriferous area should be defined with more or less accuracy. The other auriferous areas in West Pilbara are all more or less confined to the neighbourhood of the contract between the intrusive granite and the schists of allied rocks, and it is possible that there is some genetic connection between the intrusion of the granite and the quartz reefs.

Tin.—In the West Pilbara Goldfield a find of stream tin has been made near the old mining centre of Pilbara, at a locality near the junction of the schists and the intrusive granite, which forms the western margin of that area upon which the tinfield of Wodgina is situated. The tin ore is in all probability derived from those pegmatite dykes which occur at intervals along the granite contract, for tin deposits seem almost everywhere to be genetically connected with granite intrusions. Tin ores may therefore be looked for with a reasonable degree of confidence almost anywhere along the contact between the intrusive granite and the older rocks, or at no great distance from it; and if well directed prospecting is carefully carried out along this area there is every probability of other tin deposits being discovered. A portion of this huge granite mass emerges from beneath the Nullagine beds in Nunyerrie Creek, and is traversed by

many pegmatite veins which hold out the possibility of tin being found in the vicinity.

The area of metamorphic rocks between Dalgety Brook, on the Gascoyne River, and Mounts Phillips and Samuel are pierced by veins of pegmatitic granite. In the vicinity of Bilyarra Pool these make a very prominent feature in the geology, although they are not indicated by bold outcrops, being largely composed of felspar, which readily lends itself to decomposition. This area is certainly one in which tin ores may be reasonably looked for.

Lead.—Deposits of lead ore are known to occur in the district though only in one case, viz., the Silver-Lead Mine at Uaroo, have any serious mining operations been attempted.

It is very probable that other silverlead deposits will be met with, though it is by no means improbable that, their geographical situation rendering transport expenses abnormally high, it may be impossible to work them at a profit.

Copper.—The copper deposits of the district cover a very wide extent of country and appear to be of two different types, viz., copper-bearing quartz reefs traversing limestone, and those along shear zones. The latter are, however, likely to be persistent and will extend to considerable depths. The copper deposits of commercial importance seem to be those of the shear zone type, though those visited were not of very large size nor of very high grade.

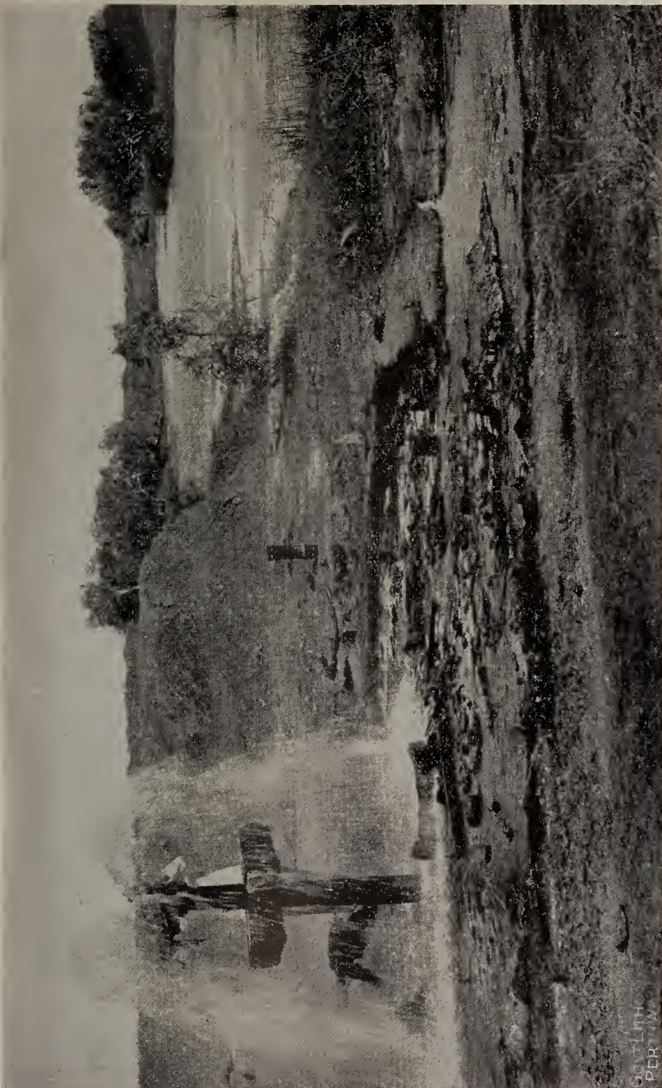
Mica.—Mica is of common occurrence in many portions of the district, but more especially in those traversed by the pegmatite dykes, which seem invariably to form the matrix of commercial mica. The mica mine, near the Pyramid on the Gascoyne River, is formed by one of these pegmatite veins, about three or four feet in width. There are several of these mica-bearing pegmatites in the vicinity, some of which seem capable of yielding quantities of mica of medium size, though their geographical situation will for a long time place them beyond the reach of possible commercial enterprise.

Artesian Water.—A very large portion of what may for convenience be called the coastal area of the district is of importance by reason of the occurrence of artesian water.

All utilitarian applications of geology being based upon a systematic examination of geological structure, in 1900 after a special examination of the country between Cue and Carnarvon, it was pointed out that in the vicinity of the latter place an artesian well might be put down with a reasonable degree of confidence.

The first bore was sunk in the district of Pelican Hill (Bibbawarra), where water was struck at a depth of 2,611 feet, and yielding 300,000 gallons per diem, but when the bore had attained a depth of 3,011 feet the supply increased to 520,000 gallons per diem. Owing to difficulties connected with the boring plant it was found impossible to continue operations until the base of the carboniferous (the water-bearing rocks) had been reached.

A photograph of the first pioneer bore in the district forms Fig. 44.



BIBBAWARRA (PELICAN HILL) BORE, NEAR CARNARVON.

Fig. 44.

This bore is of interest and importance as it has led private enterprise to do its part in embarking on a policy of water boring, and the better utilisation of those areas of pastoral country which make such an important asset in this portion of the State.

According to the latest information available there are in all 20 bores in the district referred to in the earlier pages of this report, reaching an aggregate depth of 32,096 feet; of these only two are failures, viz., Jam Thicket (Winning), and Onslow.

The deepest bore is at Maud's Landing, 2,359 feet, and the largest flow at Gladstone, viz., 2,000,000 gallons per diem.

The total output of these bores is 11,151,620 gallons per diem, which is equivalent to 4,067,341,300 gallons per annum.

The information about the artesian wells in this district has been collected and tabulated for convenience of reference in the following synoptical table:—

List of the Artesian Wells in the Gascoyne District.

Name of Bore.	Total Depth in feet.	Continuous daily flow in gallons when uncontrolled.
Bibbawara (Pelican Hill)	3,011	515,500
Boolathanna No. 1	1,650	1,000,000
Do. 2	1,392	400,000
Do. 3	1,461	470,000
Brickhouse No. 1	2,634	630,000
Do. 2	2,027	1,096,000
Do. 3	1,813	494,500
Do. 4	1,460	500,000
Gladstone	540	200,000
Griersons Tank	1,510	92,000
Jam Thicket (Winning)	2,120	(?)
Maud's Landing	2,359	654,000
Minilya Station No. 1	1,000	(?)
Do. 2	1,408	(?)
Morrel & Hearmans (near Winning) ..	1,484	1,000,000
Onslow	1,729	120 (Salt)
Wahroonga No. 1	1,281	1,200,000
Do. 2	1,181	500,000
Woora	1,226	1,500,000
Yankee Tank	850	1,000,000
Total	**32,096**	**11,151,620**

Of three of the bores, viz., Jam Thicket (Winning) and the two at Minilya, no particulars as to the flow are available.

The stock carrying capacity of the district has been greatly increased through the success of the boring, and will ultimately be reflected in an increase in the woolclip, etc.

The area over which the artesian water-bearing beds has been indicated, with as near an approach to accuracy as the scale would admit upon the two Geological Maps, forming Plates 1 and 2 of Bulletin No. 26.*

* (*a*) Possibility of the Occurrence of Artesian Water in the Northampton and Geraldin Districts. A. Gibb-Maitland. With a Map, Plate 1. (*b*) On the Country between the Ashburton and Minilya Rivers, with a view to determining the Northward Extension of the Gascoyne Artesian Area. H. P. Woodward. With a Map, Plate 2. Geological Survey Bulletin No. 26. Perth: By Authority, 1907.

PETROLOGICAL NOTES

By J. ALLAN THOMSON, B.A.; B.Sc.; F.G.S.

INTRODUCTION.

The materials on which this report is based consist of a collection of hand specimens and sections of rocks coming from the area described in this Bulletin. In addition a series of analyses made in the Geological Survey Laboratory was available. As regards field occurrence and geological position only the main outlines were known to the author, so that each rock has been regarded as a separate problem and has been separately described. It will, nevertheless, be profitable to preface these descriptions by an account of the collection as a whole.

The collection contains sedimentary and igneous rocks in about equal numbers. The sedimentary rocks are seldom unmetamorphosed although original clastic structures are not uncommon. The degree of metamorphism is, on the whole, similar to that met with in such a folded district as Cornwall, and many of the rocks are similar to types common in that district. A better parallel, however, taking into account the mineralogical compositions of the rocks, is to be found in those parts of America, South Africa, and India where stratified rocks of pre-Cambrian age overlie an Archaean complex. In these districts, besides the familiar quartzites and schists, a peculiar series of banded hematite jaspers or magnetite quartzites is found often in association with banded cherty carbonates, cherts and dolomites. The occurrence of this association of rocks in Western Australia is of practical as well as of theoretical interest, for they have frequently been found to be the "country" of exploitable mineral deposits. Mention need only be made of the iron and copper districts of the Lake Superior region, the diamond and iron deposits of Minas Geraes in Brazil, the Kolar Goldfield in Mysore, and the goldfields of the Transvaal, to show the possibilities that such rock associations offer.

Taking the rocks more in detail and noticing first those of argillaceous origin, we find phyllites containing as accessories tourmaline, garnet, hematite, and rutile. The production of these minerals demands a constructive metamorphism at a high temperature, and if it cannot be explained by the proximity of the rocks to intrusions it follows that they must have been under a considerable load of sediment or must have been greatly folded. The more siliceous rocks include arkoses, quartzites, and micaceous quartz-schists, none of which call for special mention.

A considerable place is taken in the collection by carbonate rocks among which dolomites preponderate. The different carbon-

ates are not easy of distinction in an ordinary section without having recourse to staining, but a large series of analyses leaves no doubt as to the composition of the rocks. There are a few pure marbles and dolomites, but many contain accessory minerals, such as tremolite, phlogopite, and chondrodite [**7546**], in the formation of which a process of de-dolomitisation is involved, and others again are rich in quartz. The last mineral is doubtless in some cases clastic, but more often it shows evidence of authigenous crystallisation, and is then probably due to the silification of the rock by permeating waters. None of the carbonate rocks retain any evidence of their organic origin, but some present peculiar structures which suggest that they were originally oolitic [**7547, 7726**], Figs. 60 and 62.

Practically every gradation is found between siliceous dolomites or marbles and siliceous rocks which may be conveniently called cherts. For these rocks the name "cherty carbonate" has been used where the carbonate is in excess, and "carbonate chert" where the silica is in excess. There can be little doubt that the cherts are derived from the carbonate rock by a process of silification. One of these rocks is of great interest, not only in possessing a structure which resembles oolite, but also from the fact that much of the silica is present in spherulites made up of the minerals chalcedonite and quartzine [**7727**], Fig. 63. A further point of interest about the banded cherty carbonates is that the carbonate is frequently ferriferous [**6446**].

From the cherty carbonates, again, we seem to be led by a natural gradation to ferruginous cherts or quartzites. First there are cherts which contain limonite pseudomorphs after siderite [**6411**], Fig. 48. Then follow banded rocks in which some bands are carbonate, while others consist of magnetite, hematite or limonite after siderite, and others of limonite which is apparently after hematite [**6445**], Fig. 55. Finally there are banded rocks without any carbonate.

Van Hise* is of opinion that the quartz-hematite and quartz-magnetite rocks of the Lake Superior region originate from cherty carbonates. In our rocks magnetite and siderite occur together and have no obvious connection with each other, and moreover the latter is moulded on the former (Fig. 56). Cherty carbonates are not described from all regions in which ferruginous quartzites are known and other very different views as to the origin of the latter have been put forward. It seems possible to distinguish several types among such rocks.

1. Limonite cherts, in which limonite occurs as pseudomorphs of a carbonate, *e.g.* [**6411**].

2. Limonite quartzites, in which the limonite is not obviously derived from a carbonate, *e.g.* [**6408**]. These rocks might originate by the alteration of the next three types.

* R. D. Irvine and C. R. van Hise. The Penokee Ironbearing series of Michigan and Wisconsin. 10th Ann. Rep. U.S.A. Geol. Surv., 1888-9, pt. 1, p. 341-508.

3. Hematite jaspers, e.g., the Griquatown Series of Stow* the Hospital Hill Slates ("calico rock") of the Transvaal,† jaspers of Mysore,* etc. Hematite is the predominant iron-oxide, but magnetite also occurs [c.f. **6445**].

4. Magnetite quartzites, e.g., in the Northern Transvaal,* Mysore, the Lake Superior region, the Lewisian of Scotland,* etc.

5. Pyritiferous magnetite quartzites, *e.g.*, at the Murchison River, Northern Transvaal (6).

In general, the horizon from which these rocks are described is pre-Cambrian or supposedly pre-Cambrian, but the magnetite-quartzites generally lie at a lower horizon than the hematite jaspers and may conceivably represent a more advanced stage in metamorphism. It is of course possible that they have been formed from limestones by successive processes of conversion of calcite to siderite, silification of the iron-carbonate rock, oxidation and hydration of the carbonate to limonite, and final metamorphism of the limonite to hematite or magnetite. But before accepting so complicated a theory, good reason should be shown why an original theory of sedimentation as magnetite sands and subsequent recrystallisation of both quartz and magnetite, should not be adopted. Magnetite quartzites with clastic magnetite are known in the Torridonian and in the Cambrian conglomerates of St. David's, South Wales; and on the coast of Taranaki, New Zealand, there are immense deposits of black sands, which might easily, if buried, give rise to similar rocks. It is to be hoped that this interesting group of rocks will receive further study in the near future.

The igneous rocks in the collection vary greatly in the degree of metamorphic alteration to which they have been subjected. It would be of great interest to know their relation in age to the sedimentary complex. Here again such well-studied districts as Cornwall and the Highlands of Scotland furnish us with a useful parallel. In each of these districts there is a basement series of gneisses and schists on which the sedimentaries rest unconformably. The intrusions into the latter may be distinguished as pre-folding or pre-foliation (the greenstones of Cornwall and the epidiorites of Scotland), and as newer igneous rocks intruded near the close of the main folding movement (the granites of Cornwall and the newer granites of the Highlands). Further in Scotland there are the much later tertiary volcanic rocks.

In our district the field relations are as yet too imperfectly known to be able to admit of such distinctions in all cases, but from

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1. G. W. Stow. Geological Notes upon Griqualand West. Q. J. G. S. XXX., p. 581, 1874, 2. See *e.g.*, F. H. Hatch and G. S. Corstorphine. Trans. Geol. Soc., South Africa, Vol. VII., p. 97, 1904. South African Geological literature abounds in references to these rocks. 3. There are references to jaspers and magnetite quartzites in almost every volume of the Records of the Mysore Geological Department. 4. Report on a Reconnaissance of the North-Western Zoutpansberg District. Pt. II., Geology. E. T. Mellor, p. 25. Transvaal Mines Dept., 1908. 5. J. J. H. Teall. The Geological Structure of the North-West Highlands of Scotland. Mem. Geol. Surv., Unit. King., p. 80, 1907. 6. E. T. Mellor. Transvaal Geol. Surv. Report for 1906; p. 24–52, 1907.

the degree of alteration of the rocks we may be tempted to make suggestions. The only rocks at all analogous to the Lewisian are amphibolites [6405, 6415, 6429] (Fig. 50), which show a complete reconstitution of structure. If uralitisation and saussuritisation are to be regarded as pressure alterations obeying the volume law, we may recognise a large number of rocks as pre-folding. It should be kept in mind, however, that although showing these mineral changes in great perfection, these rocks have seldom suffered as much mechanical shearing as the Scottish epidiorites, and they have been therefore termed uralitised and saussuritised dolerites. The original rocks varied considerably in composition and structure. An ophitic structure, well preserved in uralite (Fig. 45), is very general and many of the rocks appear to have been ordinary dolerites. The presence of pilite-like aggregates (Fig. 46) points to the former presence of olivine in some of them. A more hornblendic type [6419] shows a massive replacement of olivine by tremolite, as often happens in hornblende peridotites.* Still more basic types are represented by serpentines [6430, 6436]. (Fig. 51). A large number of the rocks, however, were more acid than normal dolerites, and show interstitial micropegmatite or quartz (Fig 54). There are two very fresh examples of this group of quartz dolerites which may be of later date [7616, 7728]. (Fig. 61.)

Rocks which may correspond to the newer granites are also represented [6416, 6433, 6435], but it must be remembered that under metamorphism the minerals of the acid rocks are more stable than those of the basic, and so these rocks may be of similar age to the preceding.

Besides these well-marked rock-groups, there are a number of ill-defined chloritic types whose origin is more obscure. In one of these an interesting graphic structure of quartz and calcite is to be remarked [6481] (Fig. 58). From the presence of vesicles it is probable that some of the rocks were volcanic flows.

Some aspects of the relations of the pyroxenes and amphiboles are well illustrated in many rocks of the collection, and call for mention, as a new theory of uralitisation has recently been put forward.† According to the new view the alteration of the pyroxene to amphibole takes place before the final consolidation of the rock and is due to a reaction of the residual magma, now richer in silica, alumina and alkalis than at the commencement of the consolidation, on the pyroxene where it is still in contact with the magma. That such an action does frequently take place is certain, but the development of amphibole that ensues is surely to be termed magmatic and original, and not secondary. In uralite the form of the pyrxone is retained by the amphibole, but Teall‡ has shown in the case of the Inchcolm picrite, that the primary brown horn-

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* J. A. Thomson. The Hornblendic Rocks of Glendalough and Greystones. Q.J.G.S. LXIV., p. 479, 1908.

† L. Duparc and T. Hornung. Sur une nouvelle théorie de l'ouralitisation. C.R. CXXXIX., p. 223, 1904.

‡ J. J. H. Teall. British Petrography, p. 95, 1888.

blende which forms on the augite possesses its own characteristic forms, and this seems to be the general rule in magmatic resorption. The secondary (post-consolidational) origin of uralite can scarcely be doubted in cases, such as occur in the present collection, where it occurs in association with primary hornblende; the cores representing uralitised pyroxene consist of a pale, fibrous, feebly birefringent amphibole, and the exterior consists of a compact, pleochroic, strongly birefringent hornblende, which had obviously a different origin to the former. A study of a series of analyses seems to confirm the suspicion that two modes of amphibole formation are confounded. While allowances must be made for probable differences in the composition of uralite according to the nature of the pyroxene affected, there seems to be a wide divergence between that of Duparc and Pearce's uralite, and the series quoted for comparison; moreover the former has a closer resemblance to the magmatic hornblende of the Moravian Teschenite than to other uralites.

—	1	2	3	4	5	6	7
SiO_2	52·60	52·34	54·30	52·97	52·82	55·85	52·73
Al_2O_3	5·00	3·70	4·54	1·94	3·21	0·56	4·70
Cr_2O_3	—	0·60	0·61	—	—	—	—
Fe_2O_3	—	—	—	—	2·07	—	5·26
FeO	12·04	7·39	3·87	4·52	2·71	5·22	10·21
MnO	0·63	—	—	—	0·28	0·40	—
MgO	16·55	16·43	19·01	17·49	19·04	23·99	12·57
CaO	11·54	14·88	13·72	20·47	15·39	11·66	12·57
Na_2O	0·32	2·21	2·80	1·77	0·90	—	0·23
K_2O	0·04	—	—	—	0·69	—	0·06
H_2O	1·72	1·16	0·30	0·58	2·40	2·15	1·54
Sp. Gr. ...	100·44	98·73	99·15	99·74	99·51	99·83	99·90

1. Uralite from (6434). 2. Smaragdite, Tikentscher. Jahrb. Miner, p. 84. 1864. 3. Smaragdite. T. S. Hunt. Am. J. Sci. (2) XXVII., p. 348. 1859. 4. Smaragdite. Du Toit's Pan. Story-Maskelyne and Flight. Q.J.G.S. XXX., p. 412. 1874. 5. Uralite. Templeton. Quebec. Harrington. Geology of Canada, p. 21. 1879. 6. Uralite, Reichenstein. Richter and Scheerer. Pogg. Ann. LXXXIV., p. 383. 1851. 7. Zwartkoppies. South Africa, Dahms. Jahrbk. Miner., B.B. VII., p. 90, 1890.

—	1	2	3	4	5	6
SiO_2 ...	42·22	36·91	50·91	43·34	51·28	41·24
Al_2O_3 ...	10·49	16·30	2·64	12·60		
Fe_2O_3 ...	11·98	5·28	—	10·44		
FeO ...	5·77	12·27	10·07	7·92	—	13·06
MnO ...	—	—	trace	trace	—	—
MgO ...	7·02	8·83	13·30	12·60	11·93	10·31
CaO ...	22·54	16·91	23·33	13·06	19·17	12·08
Na_2O ...	—	—	—	1·90	—	—
K O ...	—	—	—	0· 2	—	—
	102·02	96·50	100·25	101·88	100·49	100·64

1. Augite. Moravian teschenite. Teall. British Petrography, p. 95. 1888. 2. Horn blende, Moravian teschenite. Teall. British Petrography, p. 95. 1888. 3. Pyroxene. Epigabbros of Cerebriansky Duparc and Hornung, C.R. CXXXIX, p. 223. 1904. 4 Ho n blende, Epigabbros of Cerebriansky. Duparc and Hornung, C R. CXXXIX., p. 223, 1904. 5. Pyroxene of eclogites. Aiquilles Rouges. Joukonsky, C.R. CXXXIII, p. 1312-3, 1901. 6. Hornblendes derived from 5 by reaction of an acid vein

Duparc and Hornung do a great service, however, in drawing attention to the possibilities of instability of earlier formed minerals in the course of magmatic consolidation of deep-seated rocks, and to the part that mineralisators may play in the later stages. Where Rosenbusch's law holds the magma must continue to grow more acid as consolidation advances and since the earlier formed minerals are also anhydrous, if water and mineralising gases were originally present the magma must also grow richer in these. After most of the material capable of crystallising as olivine, pyroxene and plagioclase has separated out, there appears to come a period when conditions permit of the stability of the amphibole molecule: the resulting hornblende usually grows in parallel position on the pyroxene and in a great many cases is formed partly at its expense, as may be seen from the irregular boundaries between the two minerals, and from the frequent presence of hornblende only between the pyroxene and the elements of later consolidation (quartz and acid felspars). In a similar way the mica molecule seems still later to become stable, although its formation rather than that of hornblende implies a greater chemical difference than the formation of hornblende from pyroxene. Flett* has described a very clear case in which hornblende has been corroded by the final magma with formation of mica.

This outline of magmatic sequence is in accordance with the sequence of laccolitic differentiation. The earliest formed rocks are generally peridotitic or pyroxenic, and the final stages granitic, with or without the intervention of a dioritic (hornblendic) facies. It also receives confirmation from the course of events in mixed igneous rocks. It is now well established by the researches of Sollas, Harker, and others† that pyroxene xenocrysts in a granitic magma are attacked with formation of hornblende, and that hornblende xenocrysts are similarly attacked with formation of mica. It is probably due to this similarity of events that such rocks as quartz dolerites, of which this collection shows excellent examples, should be sometimes regarded as mixed rocks. Thew represent in composition a mixture of the minerals of granite and dolerite, and show these corrosion phenomena between the minerals of early consolidation and the remaining magma.

A final point of interest exhibited by the rocks of the collection is the prevalence of a red weathering crust. Even marbles almost free from iron are not excepted. This phenomena is, no doubt, to be ascribed to the arid nature of the country, since it is well known in desert weathering.

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* J. S. Flett. Explanation of Sheet 85. Mem. Geol. Surv., Scot., p. 41, Fig. 1., 1902.

† W. J. Sollas. Trans. Roy. Irish Acad., XXX. p. 493. 1894. A. Harker. The Tertiary Igneous Rocks of Skye, Mem. Geol. Surv., Unit. King., p. 173, 1904, and the Geology of the Small Isles of Inverness-shire. Mem. Geol. Surv., Scot., p. 111, 1908.

DETAILED DESCRIPTIONS.

The following abbreviations are used:—M.C.—Macroscopical characters. S.—Description of thin section.

The analyses are accompanied by a table of the molecular proportions of the molecules calculated to 100. Where the distinction exists in the analysis the hygroscopic water has been excluded from the calculations, and the combined water included. The molecular proportions are especially valuable in the case of the carbonate rocks, as showing how much of the monoxides are combined with CO_2 and the nature of the carbonate.

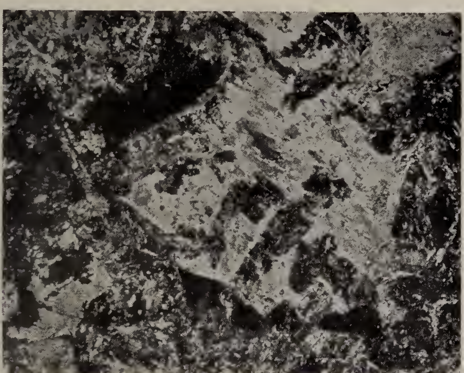
[6401]. 26 chs. S. of S.E. corner of G.M.L. 74, "Roebourne Star," Weerianna, West Pilbara Goldfield.

M.C.—A massive dark-green rock, speckled with white; of medium grain.

S.—Minerals observed: Ilmenite, leucoxene, augite, amphiboles, zoisite, and chlorite.

The rock was originally ophitic, but the original felspars and pyroxenes have been almost entirely replaced, the latter by a pale-coloured uralite which perfectly preserves the shape and twinning of the pyroxene, the former by an opaque finely granular aggregate (Fig. 45). The augite where preserved is colourless, and is confined to the centres of the larger plates. There is little ragged fringed uralite, but actinolitic needles are present throughout the felspar pseudomorphs. These are mostly isotropic, but show prussian-blue patches between crossed nicols, indicating granules of zoisite. Ilmenite was an important constituent in irregular ophitic plates, and is now represented mainly by leucoxene.

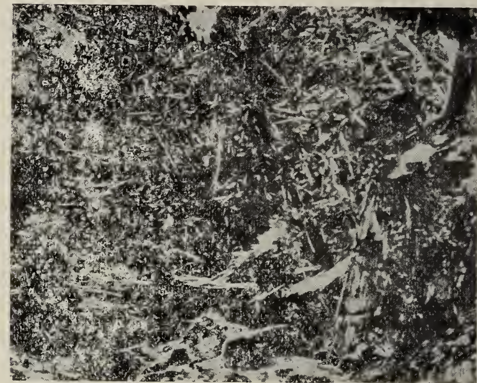
Fig. 45.



No. [6401]. An ophitic structure retained in pseudomorphs; the felspar is represented by saussurite, and the augite by uralite. Crossed nicols. x 33 diameters.

There are a few circular areas of interlacing actinolite needles in a chloritic base, which resemble pilitic pseudomorphs after olivine (Fig. 46).

Fig. 46.



No. [6401]. A mass of tangled needles of actinolite in chlorite, with a similarity to pilite. Crossed nicols. x 42 diameters.

The rock is a saussuritised and uralitised dolerite.

[6402]. 26 chs. S.E. of S.E. corner of G.M.L. 74, "Roebourne Star," Weerianna, West Pilbara Goldfield.

M.C.—A light-green fine-grained rock with an imperfect cleavage. There is considerable effervescence with dilute hydrochloric acid.

S.—Minerals observed: Chlorite, quartz, carbonates, and rutile.

The section brings to light a banded structure, to which, no doubt, the cleavage of the rock is due. There are minute faults across the bands. The alternate bands consist of carbonates and quartz, and of chlorite and quartz. The chlorite is almost isotropic, and is crowded with granules of rutile. The carbonates are untwinned, and probably include dolomite as well as the calcite indicated by the effervescence.

The rock is thus a banded quartz-carbonate-chlorite rock. Its origin is obscure; the abundance of rutile and chlorite suggests that it has arisen by the vein-alteration of a basic igneous rock.

[6404]. 55 chs. W. of S.E. corner of G.M.L. 77, "Daisy," Weerianna, West Pilbara Goldfield.

M.C.—A light greenish rock of a soapy aspect, mottled with black. The soapy lustre is due to the saussurite, which is greenish owing to the presence of epidote.

S.—Minerals observed: Ilmenite, leucoxene, hornblende, felspar, quartz, zoisite, epidote, calcite, and epidote.

The original minerals, in order of their consolidation, were plagioclase felspar, ilmenite, augite, hornblende, mica, and quartz. The felspars, which formed the bulk of the rock, are greatly altered, and are replaced by a granular aggregate of epidote, zoisite, actinolite, and apparently albite. The colourless augite and the pale brown hornblende intergrown with it formed large plates ophitic to the felspars. The

augite is now partly converted to uralite, partly to chlorite and a carbonate. Ilmenite has been mostly replaced by leucoxene, occasionally by granular sphene. Opaque brown minerals, moulding felspars, hornblende, and ilmenite are taken to be pseudomorphs after biotite, as in places they preserve the structure of bent lamellae. The quartz was the last element of consolidation filling the angular interspaces between the other minerals.

The rock is a saussuritised quartz-hornblende-dolerite.

[6405]. 40 chs. E. of G.M.L. 5, "Herman's Reward," Weerianna, West Pilbara Goldfield.

M.C.—A fine-grained massive rock with a thin brick-red crust.

S.—Minerals observed: Hornblende, iron ores, leucoxene, chlorite, and zoisite.

The bulk of the rock is formed by a pale-green hornblende, which resembles a sponge whose pores are filled with chlorite, or a fine saussurite containing zoisite. Iron-ores and small patches of leucoxene are scattered throughout the rock. No trace of original structure can be found.

The rock is an amphibolite.

[6408]. Hill 25 chs. N. of G.M.L. "Eureka," Weerianna, West Pilbara Goldfield.

M.C.—A banded rock with clearer bands of fine-grained quartz, and more opaque bands of a rusty colour, with a colour of magnetite in the centre of the denser bands.

S.—Minerals observed: Quartz, iron-ores, rutile, a carbonate, and sillimanite.

The rock consists of alternate layers of a fine-grained mosaic of polygonal quartz grains in which microscopic accessories occur, and layers of a similar mosaic almost obscured by a plexus of needle-shaped growths of a rusty-coloured iron-hydrate (Fig. 47). The latter is birefringent

Fig. 47.

No. [6408]. Banded ferruginous Quartzite. At the bottom is a limonite band, and cicular groups of limonite are seen in the quartz mosaic above. x 9 diameters.

fringent, and appears to be göthite from its habit. It may be derived from magnetite, which occurs in idiomorphic octohedra in the middle of the hydrate bands, but there is also the possibility that it represents pseudomorphs of acicular hematite. The presence of a small amount of a carbonate was revealed by a slight effervescence when a portion of the powdered rock was dropped into hot acid. The minute minerals in the clearer bands are of too small size to permit of their determination when embedded in the quartz. Needles resembling sillimanite and small prisms suggesting rutile are abundant. There are also minute hexagonal plates of an opaque mineral, probably hematite, and rounded plates of a colourless mineral of high birefringence, probably a carbonate.

The rock is a banded ferruginous quartzite.

[**6409**]. S.W. corner of G.M.L. 90, "Golden Pile," Weerianna, West Pilbara Goldfield.

M.C.—A brown-grey rock of medium grain, with a parallel structure that is well brought out in the weathered parts. A red crust.

S.—Minerals observed: Quartz, chlorite, carbonates, iron-hydrates.

The rock is finely banded by the accumulation of small shreds of chlorite along certain layers. The chlorite is almost isotropic, and between crossed nicols is scarcely distinguishable in the fine quartz mosaic. Quartz is the predominant element in small extremely irregular grains. There are a few ragged crystals of a highly refringent carbonate, which from its mode of alteration into iron-hydrates appears to be ferruginous.

The rock is a banded quartz-chlorite rock rich in iron-hydrates.

[**6410**]. 80 chs. E. of G.M.L. 90, "Daisy," Weerianna, West Pilbara Goldfield.

M.C.—A massive, medium-grained greenish rock, with patches of pyrites in green epidotic segregations. A dark-red crust.

S.—Minerals observed: Ilmenite, leucoxene, pyrites, diallage, brown hornblende, epidote, chlorite, and quartz.

The felspars are represented by opaque granular aggregates, of which the only determinable constituent is epidote along the cracks and edges. The felspar was inferior in amount to the diallage, which neverthe less occasionally encloses it ophitically. The ilmenite and its pseudomorph in leucoxene often partially surround the diallage, but are separated by a thin fringe of pale brown hornblende. The relations of the hornblende and the diallage suggest that the latter suffered a magmatic corrosion during crystallisation of the former. There is a large pseudomorph with the outward appearance of serpentinised olivine, but the replacing minerals appear to be chlorite in the cracks and quartz in the cores.

The rock is a saussuritised (olivine?) gabbro.

[**6411**]. 4 chs. S. of S.E. corner of G.M.L. 90, "Golden Pile," Weerianna, West Pilbara Goldfield.

M.C.—A banded rock of flinty texture; one band an inch thick is of a dark colour like a chert, others are redder and jasperoid. Some bands are drusy and show strings of magnetite.

S.—Minerals observed: Quartz, carbonates, limonite, and chlorite.

The section shows a very fine-grained mosaic of quartz with the most highly irregular boundaries between the grains. In this lie sporadic

crystals of a clear carbonate, a few needles of a chloritic mineral, and limonite, both as a fine dust, and as pseudomorphs of siderite (Fig. 48).

Fig. 48.

No. [6411]. Chert showing on the left carbonates and on the right limonite pseudomorphs of a carbonate. x 37 diameters.

Both the carbonate and the limonite occur in the form of honey-combed rhombohedra, with inclusions of quartz. The carbonate shows great difference of relief and absorption when rotated and viewed with the polarisator alone. It so seldom contains limonite, and on the other hand the limonite pseudomorphs are so complete, that it is probable that the intact carbonate is dolomite, and that siderite was present and has wholly disappeared. The banding is due to the aggregation of the carbonates in certain rows. A few thin veins of a coarser quartz mosaic cut the rock. They also contain carbonates.

The rock is a banded carbonate-chert.

[6412]. 40 chs. S.W. of G.M.L. 75, "Welcome," Weerianna, West Pilbara Goldfield.

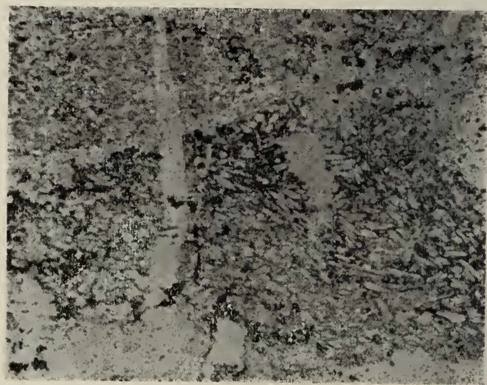
M.C.—The rock is very much broken up by two series of siliceous veins; of these one is black and flinty, the other is white, coarse, and saccharoidal, and cuts the former at right angles. The ''country'' of the veins is a dense green rock mottled with quadrate or rounded white spots.

S.—Minerals observed: Quartz, carbonates, iron-ores, muscovite, and tourmaline.

The three parts made out in the hand specimen can be clearly distinguished in section. The coarse vein is formed of large hexagonal prisms of quartz, set mostly at right angles to the walls of the vein. The quartz includes numerous minute rhombohedra of carbonate and limonite pseudomorphs of the same. The flinty veins occasionally consist in the centre of the fibrous form of silica chalcedonite, arranged in subparallel vectors. The outer parts of these and the whole of the smaller veins consist of fine mosaics of highly irregular quartz grains. There are numerous inclusions of carbonate and limonite similar to those in the sugary quartz. In one vein there is a broken prism of tourmaline. The white spots in the rock have a concentric structure,

due to layers of opaque matter which is light red brown in reflected light. Their interiors are filled with a fine quartz mosaic similar to that of the flinty veins, containing again idiomorphic carbonates. Finally there are parts of the section, corresponding apparently to the green cement of the rock, which show in ordinary light small, clear, rounded or lath-shaped spaces in a dusty ground mass (Fig. 49).

Fig. 49.



No. [6412]. Chert showing an original structure. x diameters.

Between crossed nicols these structures disappear, as both clear spots and groundmass are composed alike of a fine quartz mosaic with occasional minute carbonates, iron-hydrates, and flakes of sericitic mica.

Whatever the original nature of the rock, it appears to be highly silicified. It has more resemblance to a spherulitic felsite than to an oolitic limestone, though both are possible interpretations. It is now a veined chert.

[6414]. 50 chs. S.W. of G.M.L. 75, "Welcome," Weerianna, West Pilbara Goldfield.

M.C.—A massive greenish rock of coarse grain, showing fibrous tufts of a pale-green hornblende. A red crust.

S.—Minerals observed: Leucoxene, pyrites, augite, uralite, and felspar.

The rock was originally an ophitic dolerite, with augite and felspar in nearly equal proportions. A little colourless augite is still preserved in some of the plates of uralite. The latter does not generally extend beyond the boundaries of the original augite, but there is much actinolite within the felspar pseudomorphs, and there are, in addition, a few acicular aggregates suggesting pilite after olivine. The felspar has not been entirely replaced, and twinning after the albite and pericline laws may be observed, but the exact species of plagioclase defies determination. Ragged plates of leucoxene after ilmenite are abundant throughout the rock.

The rock is a uralitised dolerite.

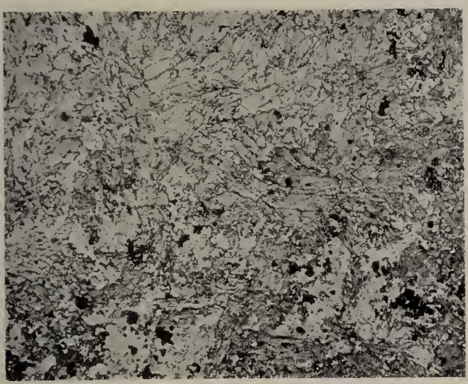
[6415]. 50 chs. N. of G.M.L. 90, "Golden Pile," Weerianna, West Pilbara Goldfield.

M.C.—A dark green massive rock of fine even grain. A red crust.

S.—Minerals observed: Green hornblende, iron-ores, epidote, quartz, calcite, and chlorite.

The predominant constituent is a bright grass-green actinolitic hornblende, with a general parallel arrangement somewhat obscured by transverse and oblique fibres. The iron-ores form spongy masses mostly within the hornblende. The spaces between the hornblendes are filled with a colourless mosaic mainly of quartz. There is a little epidote and calcite (Fig. 50).

Fig. 50.



No. [6415]. An Amphibolite. x 37 diameters.

The rock is an amphibolite.

[6416]. 90 chs. S.E. of G.M.L. 72, Weerianna, West Pilbara Goldfield.

M.C.—A massive grey rock of granitic texture; the felspars mostly dull. Hornblende and chlorite are recognisable with the unaided eye.

S.—Minerals observed: Apatite, zircon, iron-ores, leucoxene, felspars, muscovite, hornblende, biotite, and chlorite.

The rock is somewhat altered, the iron-ores being partially converted to leucoxene, the felspars opaque in the centre and filled with muscovite, and the biotite almost entirely weathered to chlorite. Hornblende is moulded on the plagioclase, but the most noticeable structural peculiarity of the rock is that where the hornblende and quartz are contiguous, the hornblende is ragged and sometimes honeycombed. This is probably due to a corrosion, as described in the introduction. Felspar occurs in two habits, as large idiomorphic crystals of oligoclase, sometimes zoned and altered in the centres, and frequently with an external zone of orthoclase, and also as allotriomorphic plates forming a coarse mosaic with quartz. These latter felspars belong mostly to orthoclase, but sometimes show perthitic intergrowths, presumably of orthoclase and albite.

The rock is a hornblende-granite.

[**6419**]. 20 chs. S. of G.M.L. 72, Weerianna, West Pilbara Goldfield.

M.C.—A massive greenish rock of very coarse texture, with a lustre mottling exhibited on the cleavage surfaces of large pale-green hornblende crystals. A reddish crust.

S.—Minerals observed: Amphiboles, leucoxene, chlorite, diallage, felspar, zoisite, muscovite, and limonite.

The predominant minerals are the amphiboles, part of which appears original, as it is brown and pleochroic, and contains rounded patches of colourless tremolite, thus retaining evidence of an original poecilitic structure. From the analogy of similar rocks, it seems probable that this tremolite is replacing olivine. There is also an extensive uralitic replacement of diallage, the resulting amphibole being pale, but with a much lower birefringence than the tremolite which is in continuity with the brown hornblende. The various amphiboles are in course of alteration to chlorite, chiefly chlinochlore. The diallage, which survives in the centre of the larger uralitic plates, was ophitic to the felspar. The latter is almost entirely altered to an aggregate of zoisite, epidote, and muscovite.

The rock was originally a basic hornblende-olivine-gabbro, and is now almost a hornblende rock.

[**6421**]. 15 chs. S.E. of Specimen [**6420**], Glen Roebourne, West Pilbara Goldfield.

M.C.—A massive rock with a porphyritic structure poorly exhibited by the felspars. The groundmass is coarsely crystalline and speckled.

S.—Minerals observed: Iron-ores, felspar, hornblende, quartz, chlorite, and zoisite.

The felspars are greatly altered to opaqne saussuritic aggregates, and rarely show original structures such as twinning. Such as can be determined seems to be an intermediate species. The pseudomorphs are enclosed ophitically by plates of brown-green hornblende, while quartz fills up the interstices. Possibly there was some original micro-pegmatite. The hornblende is rarely uniform in colour, and may have contained augite cores since uralitised. Chlorite and iron-ores are alteration products of the hornblende, but no doubt some of the ores are original accessories, while occasionally the chlorite seems to represent original biotite.

The rock is a saussuritised quartz-diorite with affinities to the quartz-hornblende-dolerites.

[**6422**]. 45 chs. N.W. of G.M.L. 60, Glen Roebourne, West Pilbara Goldfield.

Field occurrence—Possibly the same rock-mass as [**6421**].

M.C.—A pale coloured massive rock of flinty aspect, with a few dark specks and some scattered crystals of pyrites.

S.—Minerals observed: Quartz, felspars, muscovite, chlorite, zircon, iron-ores, and calcite.

The main part of the rock is formed of a fine mosaic of quartz and felspars in about equal amounts. The boundaries between the two minerals possess the highest degree of irregularity. The felspars are much affected by strain shadows, and consist of both twinned and untwinned varieties, but both with refractive indices lower than those of quartz. In this matrix lie gronps of larger individuals of quartz and occasionally of micro-perthite. Scattered flakes of a green chlorite are

abundant, and may be seen in places to arise from the decomposition of biotite. There is a little muscovite, much allotriomorphic calcite, and occasional grains of pyrites altering to limonite. The chief original accessory was zircon.

The rock is a deformed acid intrusive.

[6426]. 30 chs. N.W. of G.M.L. 35, Glen Roebourne, West Pilbara Goldfield.

Field occurrence—The same mass as [6427].

M.C.—A green translucent rock of flinty texture, crossed by a light-coloured quartz vein of sugary aspect. The rock has the general appearance of museum specimens of prase.

S.—Minerals observed: Quartz, carbonates, mica, and iron-hydrates.

The quartz forms an extremely fine-grained mosaic of irregular individuals, in which lie scattered sporadic crystals of a carbonate. From its very great difference of relief on rotation it appears to be dolomite or siderite. The larger individuals never show perfect crystal form, although often approaching it, but the smaller ones occur in perfectly-shaped rhombohedra. The mica is disseminated in little acute flakes, rarely in broader plates, and appears to be muscovite. The small proportion of iron-ores occurs in patches without definite form and appears to be limonite.

The rock is a chert.

[6427]. 35 chs. N.W. of [6428].

Field occurrence—From the same mass as [6426].

M.C.—A massive greyish-green finely crystalline rock, with a few irregular siliceous blue veins. A brown crust.

S.—Minerals observed: Carbonates, quartz, iron-ores, and chlorite.

Where the rock is free from veins, it is seen to have a pavement-structure of clear carbonates. But the greater part of the slide shows either parallel veins of fine quartz, with minute rhombohedra of carbonates and shreds of chlorite, or nests of quartz into which large idiomorphic carbonates project. The iron-ores occur in idiomorphic cubes in association with the quartz, and their forms are preserved in pseudomorphs which are yellow in reflected light, but there is also a little cloudy reddish hydrate. The carbonates are only rarely twinned, and are probably dolomite.

The rock appears to be a silicified dolomite.

[6429]. Two miles N.E. of Mt. Marie, near Roebourne, West Pilbara Goldfield.

M.C.—A dark greenish rock of fine grain; there is an imperfect parallel structure indicated by white saussuritic veins. A reddish crust.

S.—Minerals observed: Iron-ores, hornblende, zoisite, epidote, quartz, and plagioclase.

The most abundant mineral is a pleochroic blue-green hornblende in irregular, often honeycombed, plates. It includes iron-ores, both ilmenite (leucoxene) and magnetite, and the colourless minerals of the matrix. The latter is mostly of quartz, but some undoubted plagioclase occurs. A few large aggregates, which may represent former porphyritic felspars, are composed of minerals of the epidote group, clinozoisite, and epidotes poor in iron, along with calcite, quartz, pyrite, and possibly albite.

The rock is an amphibolite.

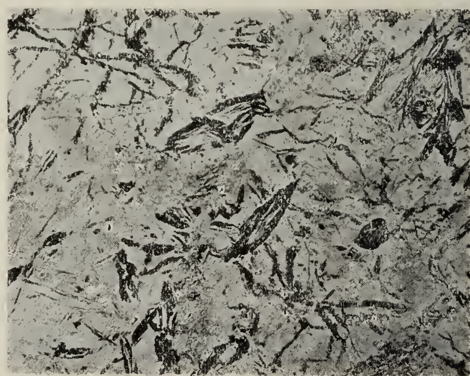
[6430]. Hill near Mt. Hall, near Roebourne, West Pilbara Goldfield.

M.C.—A dark-green massive rock with a moderately coarse granular texture; the weathered crust is red, and shows a honeycombed aspect.

S.—Minerals observed: Serpentine, chlorite, iron-ores, and tremolite.

The serpentine occurs in numerous radially-fibrous plates forming pseudomorphs with a "gitter" structure. The species is crysotile, and not antigorite, which is the usual variety in "gitter" structures. The pseudomorphs appear to be after olivine, for irregular lines of dusty magnetite cross them in a manner recalling the cracks of olivine. The chlorite is a colourless variety, optically agreeing with pennine, but with peculiar bistre interference colours. It occurs in elongate fibres, and bears lines of magnetite in its longitudinal cleavages (Fig. 51).

Fig. 51.



No. [6430]. Serpentine with a peculiar habit of chlorite. x 28 diameters.

The tremolite forms stout prisms intimately associated with the chlorite, and the two minerals seem to replace an earlier poecilitic element which was moulded on the idiomorphic olivine. From some relict schiller-structures in the tremolite, this earlier mineral appears to have been diallage, but there may have been others.

The rock is a chlorite-tremolite-serpentine.

[6432]. Top of Black Hill, 3½ miles W. of Mt. Gregory, near Roebourne, West Pilbara Goldfield.

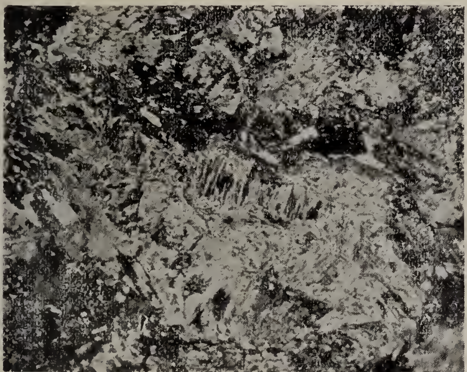
M.C.—A mottled greenish massive rock of moderate grain, composed of greenish saussurite and somewhat elongated hornblende.

S.—Minerals observed: Hornblende, chlorite, felspars, quartz, leucoxene, zoisite, and epidote.

The original minerals are largely represented by pseudomorphs, but the structure is still preserved, and can be seen to have been both ophitic and micropegmatitic. Ilmenite in characteristic forms is largely replaced by leucoxene. The original pyroxene is now represented by a

fibrous, greenish, slightly pleochroic hornblende, together with some chlorite. So completely is the form and structure of the pyroxene preserved that a "herring-bone" structure is still to be made out (Fig. 52).

Fig. 52.



No. [6432]. Uralite pseudomorphosing the herring-bone structure of the augite. x 35 diameters.

There is, in addition, some strongly pleochroic hornblende on the outer margin of the uralite, which is to be regarded as original. A chlorite of different habit and nature to that in the pyroxene pseudomorphs points to a small proportion of original biotite. The form of the plagioclase is preserved in lath-shaped pseudomorphs of a saussuritic aggregate, but some of the original mineral may occasionally be seen. A relatively coarse intergrowth of quartz and orthoclase is abundant, and there is, in addition, some interstitial quartz not occuring in the intergrowths. The orthoclase is wonderfully fresh, and this seems to show that the changes that have affected the rock are due rather to a pressure-metamorphism than to ordinary weathering.

The rock is a uralitised and saussuritised quartz-dolerite.

[6433]. Foot of Black Hill, 3½ miles W. of Mt. Gregory, near Roebourne, West Pilbara Goldfield.

M.C.—A massive grey rock of granitic texture; the felspars are mostly lustrous, occasionally dull; the ferro-magnesian element is small in amount.

S.—Minerals observed; Iron-ores, apatite, zircon, felspars, biotite, chlorite, epidote, zoisite, and muscovite.

The original minerals may be recognised as belonging to two fairly distinct times of consolidation; the earlier terminated with the formation of large euhedral crystals of an acid plagioclase (oligoclase), which is moulded on the smaller crystals of biotite, and like it includes the accessories and iron-ores. The plagioclase is often slightly decomposed, with the formation of muscovite and occasional grains of zoisite, and the biotite is in course of alteration to chlorite and epidote. Before

the final consolidation, the biotite seems to have been corroded, as it presents very irregular contours to the fine-grained quartz-orthoclase mosaic, and occurs in ragged flakes within it.

The rock is a biotite-granite.

[6434]. Summit of Mt. Gregory, near Roebourne, West Pilbara Goldfield.

M.C.—A mottled rock of very coarse texture, composed of dull white saussurite and dark green uralite. It shows an extremely close resemblance to the gabbro-pegmatites of the Lizard, Cornwall.

S.—Minerals observed: Uralite, epidote, zoisite, and felspar.

An ophitic structure is retained in the pseudomorphs. The diallage has been converted to a uralite, which still retains in places relicts of the schiller-structure in the form of rows of fine iron-oxides transverse to the cleavage traces. In places the uralite is almost actinolitic, and is not entirely confined to the boundaries of the original diallage. The pleochroism is:—X blue-green, Y yellow-green, and Z pale yellow. No sections suitable for determining the axial angle or the maximum extinction presented themselves. The felspar has been entirely saussuritised with formation of zoisite, epidote, and acid felspars.

The rock is an uralitised and saussuritised gabbro-pegmatite.

Note.—The "green actinolite" (uralite) was separated and analysed. After four separations with methylene iodide solution, the material for analysis was carefully hand-picked under a lens to secure purity from contamination.

	Analysis.	Molecular percentage.
SiO_2	52·60	48·09
Al_2O_3	5·00	2·69
FeO	12·04	9·17
MnO	0·63	0·49
MgO	16·55	22·69
CaO	11·54	11·31
Na_2O	0·32	0·29
K_2O	0·04	0·02
Loss on ignition ...	1·72	5·25
	100·44	100·00

Sp. Gr. at 4° = 3·089.

The significance of this analysis as bearing on the question of uralisation has been discussed in the introduction. It remains to consider it as an analysis of an amphibole. Penfield and Stanley have shown* that the amphibole molecule is more complex than has been generally supposed. Especially it is to be noticed that water is an important constituent; and that (OH) and F. are mutually replaceable. Owing to the absence of a determination of the fluorine (and apparently no analysis of uralite complete in this respect has yet been made) it is impos-

* On the Chemical Composition of Amphibole. Am. I., Sci., XXIV. p. 23., 1907.

sible to discuss the analysis in detail. It may be pointed out, however, that it bears out Penfield's remark that the commonly accepted conclusion that the ratio of CaO to MgO + MnO + FeO equals 1:3 is inexact, but that the CaO + alkalies replace very nearly 25 per cent. of the hydrogen atoms of the amphibole acid. The actual figures are 23.33 per cent. when water of ignition is included among the bases, and 26.08 per cent. when it is excluded. The actual ratio, depending on a knowledge of the combined water and of fluorine, must lie between these figures.

[6435]. N. side of Mt. Gregory, near Roebourne, West Pilbara Goldfield.

M.C.—A grey rock of granitic texture, with abundant quartz. The felspars are mostly dull white and the ferro-magnesians dull black.

S.—Minerals observed: Apatite, hornblende, biotite, felspars, quartz, zoisite, and epidote.

The chief structural peculiarity is the breaking up of the hornblende by corrosion, as described in the introduction, and the association of the biotite with the hornblende. An acid plagioclase is among the earlier elements of consolidation, and occurs in large idiomorphic prisms, cloudy with granules of epidote. The later felspars, orthoclase, microcline, and microperthite, form a clear, moderate-grained matrix with quartz, and are sometimes intergrown in graphic structure with it. The biotite is mostly altered to chlorite, and the hornblende in part to chlorite and epidote.

The rock is a hornblende-granite.

[6436]. Three miles N.W. of Mt. Gregory, near Roebourne, West Pilbara Goldfield.

M.C.—A massive reddish-brown rock, of a general dull aspect, but with occasional glistening flakes. A fine parallel veining can be made out with a lens. There is a rich brick-red crust with a honeycombed structure.

S.—Minerals observed: Biotite, serpentine, iron-ores, chlorite, and a carbonate.

The rock consists mainly of serpentine with a pronounced mesh-structure, the irregular streaks of iron-ores being lined with perpendicularly set fibrous chrysotile, while the interiors of the polygons thus formed are isotropic or nearly so. There are also some deeply pleochroic biotite, chlorite similar to that in [**6430**], and a few grains of carbonate. Some of the iron-ores are altered to limonite.

The rock is a biotite-chlorite-serpentine.

[6437]. Three miles N.W. of Mt. Gregory, near Roebourne, West Pilbara Goldfield.

M.C.—A massive speckled rock of medium grain, with dull felspars and dark green ferro-magnesian minerals.

S.—Minerals observed: Augite, uralite, felspar, iron-ores, epidote, zoisite, and chlorite.

The pyroxene has often rows of inclusions of iron-ores oblique to the longitudinal cleavage traces. It is ophitic to the felspar. Uralite is developed only at the periphery of the crystals or along cracks. The felspar is a good deal altered, but small fragments giving the extinction angles characteristic of andesine are still intact. The rest is altered to a saussuritic aggregate with the usual minerals.

The rock is a partially uralitised and saussuritised dolerite.

[6439]. Summit of Mt. Anketel, West Pilbara Goldfield. Only an analysis furnished.

—	I.	II.	III.	IV.	V.	VI.
SiO_2	53·11	53·81	53·58	53·46	54·56	51·64
TiO_2	0·40	2·01	0·98	0·70	0·53	0·29
Al_2O_3	15·55	13·48	15·84	14·81	16·04	8·90
Fe_2O_3	1·26	3·02	2·98	2·60	0·95	0·46
FeO	7·17	7·39	4·90	5·15	6·07	5·81
MnO	0·59	trace	..	0·18	0·17	0·48
MgO	6·50	6·46	7·16	7·27	8·71	9·48
CaO	8·93	10·34	7·86	8·44	8·89	9·31
Na_2O	3·03	3·23	2·99	2·64	3·05	2·85
K_2O	0·28	0·64	1·63	1·30	1·18	0·17
H_2O+	3·12	0·57	2·54	2·13	..	10·11
H_2O-	0·04	..	..	0·12	0·28	..
P_2O_5	..	..	0·19	0·44	..	..
CO_2	0·32	..	..	0·16	0·18	0·43
Fe	0·03	..	..	0·26	..	0·03
S_2	0·04	..	..		..	0·04
	100·37	100·95	100·81	99·76	100·64	100·00
Sp. Gr. ..	2·91	2·75	2·76	..	..	..

I. [6439.]
II. Basalt-obsidian. Kilauco. Rosenbusch. Gesteinslehre, p. 323, 1901.
III. Navit. Mittweiler. Rheinpreussen. Rosenbusch. loc. cit., p. 325 ($SO_3 = 0·16$).
IV. Diorite, strongly altered. Sonora Tuolumne Co., California. Clarke. Bull. U.S.G S., No. 168, p. 2[illegible]4. (NiO = 30·05 BaO = 0·05; traces of Li_2 O and SrO).
V. Quartz basalt. Cinder cone Colorado. Clarke. loc. cit., p. 185. (BaO, 0·03.)
VI. Molecular percentage of [6439].

It is difficult to find any analyses that approximate more nearly to [6439] than those given above. From the large amount of combined water it is probable that the rock is much altered. The analysis, however, evidently places the rock among the basic igneous rocks.

The following is a description of this by Mr. L. Glauert:—

[6439]. (Micro section 691.)

M.C.—A close-grained greenish rock of felsitic structure, similar to [7562] and [7563] but rather coarser grained and without traces of amygdaloidal structure. The fracture is conchoidal. Very slight effervescence with cold acid. Sp. Gr. 2.91. Where exposed to the atmosphere becomes coated with a reddish brown crust.

S.—Minerals: Plagioclase, felspar, augite, olivine, serpentine, and a little epidote quartz.

The rock consists of a base composed of small felspar crystals (microlites) giving undecided polarisation colours and some partly altered glass and saussurite—an alteration product of the felspars—in which are phenocrysts of altering augite, felspar, olivine, and serpentine, etc. Iron ores, magnetite, ilmenite, etc., are conspicuous by their absence, a rather remarkable fact in a rock containing nearly 8.5 per cent. of Fe_2O_3 and FeO; the explanation is that the iron is all present as a constituent of ferro-magnesian minerals, etc. The ¼ obj. reveals many small opaque specks, which are probably magnetite; they are, however, very minute and not too abundant. This absence of iron ores is noticed in some of the lavas, the andesites, from which this specimen differs in absence of amygdules, and in having a higher sp. gr., that of a

typical andesites being about 2.75. The abundance of augite would indicate that the rock is an augite-andesite, but these rocks, being again basic variety of the group, have an abundance of magnetite.

The rock is doubtful to place, but the name andesite is perhaps the most appropriate. Augite-andesite without magnetite might represent its characters more distinctly. The rock is much altered.

[**6440**]. Near Seabeach, two miles from Mt. Anketell, near Roebourne, West Pilbara Goldfield.

M.C.—A massive dark green rock of very fine grain, with a well marked amygdaloidal character. The amygdalules are partly of calcite and partly of chalcedony, and appear as vesicles on the weathered surface.

S.—Minerals observed: Leucoxene, chlorite, quartz, and calcite.

With the polariser only, the slide presents the aspect of a microlitic igneous rock, in which the iron-ores are altered to spongy masses of leucoxene, and the base and the ferro-magnesian minerals are represented by a grass-green pleochroic chlorite. The colourless portions of the slide have the shapes of small rectangular phenocrysts and acicular microlites of felspars. On introducing the analyser, however, the resemblance disappears, for the presumed felspars resolve themselves into micro-crystalline mosaics of quartz, differing little in polarisation colours from the chloritic base. The analyser reveals in addition the presence of a few small flakes of muscovite. A coarser-grained vein of chlorite, quartz, and a carbonate crosses the section.

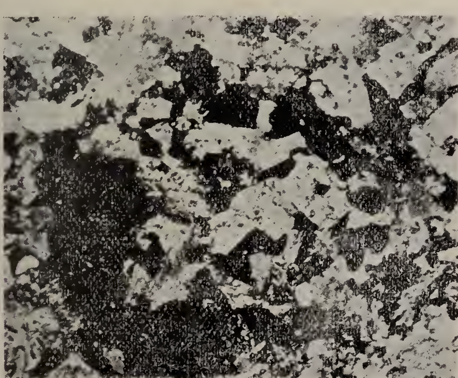
The rock is a decomposed, vesicular, igneous rock, probably a porphyrite or andesite.

[**6441**]. Loc. 65, N.E. corner, near Roebourne, West Pilbara Goldfield.

M.C.—A light greenish-yellow rock of fine granitic texture, somewhat drusy.

S.—Minerals observed. Felspars, quartz, micas, calcite, limonite, and kaolin.

Fig. 53.



No. [6441]. A large plate of quartz (in position of extinction) enclosing poecilitically altered felspars. Crossed nicols. x 30 diameters.

The rock appears to have been a fine-grained biotite-granite, but it has undergone a considerable alteration, possibly by the agency of heated waters. It now consists of euhedral prisms of oligoclase, strongly muscovitised, and rounded plates of kaolinised orthoclase, enclosed in large poecilitic plates of quartz (Fig. 53). There are large flakes of a mica with pleochroism from pale yellow to colourless, and strong birefringence, which appears to be a bleached biotite. The iron-ores are altered to limonite, and there is a considerable development of calcite.

The rock is an altered granite.

[**6442**]. S.W. corner of Loc. 42, near Roebourne, West **Pilbara** Goldfield.

M.C.—A massive grey rock of rather fine grain, with a very evenly distributed speckling of dark green. A red crust.

S.—Minerals observed: Diallage, labradorite, uralite, calcite, zoisite, and chlorite.

The structure is ophitic, the diallage plates being moulded on the felspar, but not enclosing it. Uralitisation has affected only the outside of the diallage, and a good deal of the felspar has escaped saussuritisation. It may then be determined as labradorite. There is a fair amount of migrated uralite in the form of actinolitic needles in the altered felspars.

The rock is a uralitic gabbro.

[**6443**]. S. of G.M.L. "Carlow Castle," Glenroebourne, West Pilbara Goldfield.

M.C.—A coarse-grained rock with a rude parallel structure, consisting of dark elongated hornblendes in a greenish saussuritic matrix.

S.—Minerals observed: Ilmenite, leucoxene, hornblende, quartz, epidote, and calcite.

Although the original felspar is entirely altered to a saussuritic aggregate in which epidote predominates, the original structure of the rock is well preserved. The felspars formed elongated and sub-parallel rectangular prisms, around and between which the ferro-magnesian

Fig. 54.

No. [**6443**]. A uralitised quartz-dolerite showing the interstitial nature of the quartz. x 21 diameters.

minerals have grown, giving rise to a peculiar type of ophitic structure characterised by the abundance of acute triangular plates of hornblende. The larger ophitic plates are now composed of a compact brownish-green pleochroic hornblende and a pale fibrous uralite in crystallographic continuity with each other, the pleochroic variety being mainly confined to the exterior. It is therefore probable that there were augite cores to the hornblende plates. Sometimes the interior of the hornblende is replaced by quartz and calcite, and in other places pleochroic yellow-green epidote seems to occupy the place of the interstitial triangular hornblendes. Leucoxene, representing a titaniferous iron-ores, also forms irregular plates embracing the felspars The last element of consolidation was quartz, which is found in interstitial plates; often several adjoining plates are found in optical continuity, giving rise to an appearance resembling a rude graphic structure, whereas it is really an ophitic structure (Fig. 54). Where the quartz touches the hornblende, the latter is spongy, but in so altered a rock it would be unsafe to assume that this is an original corrosion phenomenon.

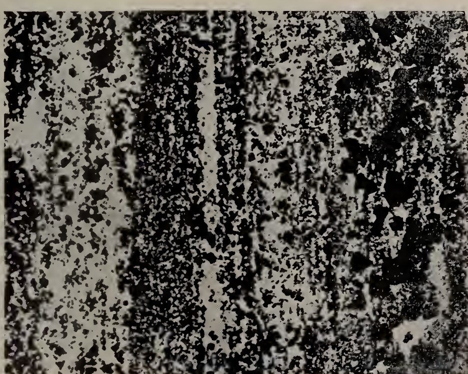
The rock is a saussuritised and uralitised quartz-hornblende-dolerite.

[6445]. Near Mt. Margaret, Hamersley Range, Fortescue River, West Pilbara Goldfield.

M.C.—A well-banded rock, the bands being alternately dark and flinty, or rusty with cores of lustrous black magnetite.

S.—Minerals observed: Quartz, magnetite, hematite, limonite, and carbonates.

Fig. 55.

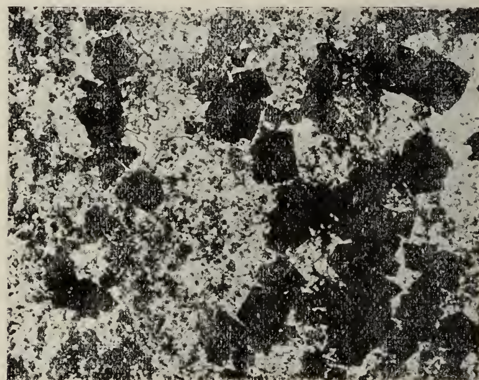


No. [6445]. Banded ferruginous quartzite. To the right is a band with large crystals of magnetite, to the left of the middle a band of spongy hematite. The white is quartz. x 7 diameters.

The section has a finely banded structure (Fig. 55); the bands are of varying width, and present the greatest variety when compared with one another. All have an extremely fine quartz mosaic as a base, but

the texture of the mosaic is variable in the different bands. We may distinguish clear bands, with or without carbonates, and dark bands rich in iron-ore. The latter are sometimes black in reflected light, owing to the presence of magnetite, or hematite, and sometimes red owing to the presence of iron-hydrates. The hematite, recognised by a blood-red colour on its borders, appears to be allotriomorphic, and forms a fine sponge or sieve-like structure with the quartz. The magnetite, on the other hand, has crystallised in stout octohedra. The carbonates are partly collected in separate bands of idiomorphic rhombohedra, but in places are clearly seen to be moulded on the magnetite (Fig. 56), and sometimes are invaded by the quartz mosaic, and

Fig. 56.



[6445]. Part of the above with greater magnification. On the left the crystals of carbonate may be seen to be moulded on the magnetite. x 43 diameters.

appears to have been corroded. They are in course of alteration to limonite, and may therefore be ascribed to siderite. There are further minute indeterminable accessories. The quartz of the mosaic shows interlocked outlines and undulose extinctions, but these are probably due to the overlapping of adjacent plates.

The rock is a ferruginous quartzite, jasper, or chert. A suitable name has yet to be proposed for this class of rock.

[**6446**]. Near Mt. Margaret, Hamersley Range, Fortescue River, West Pilbara Goldfield.

M.C.—A dark thin-banded rock of flinty aspect, alternately light and dark in colour.

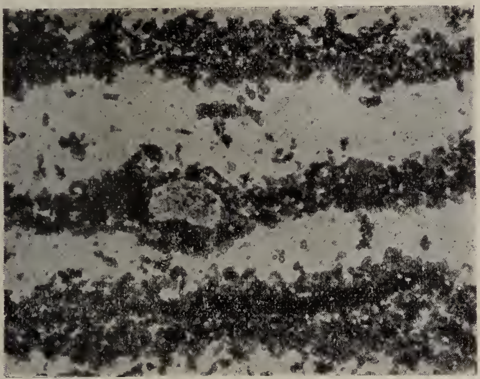
S.—Minerals observed: Quartz, carbonates, iron-ores, and rutile.

The section is made up of a fine-grained mosaic of interlocking quartz grains, in which lie rhombohedra of the carbonate, sometimes scattered sporadically, sometimes collected in definite bands almost to the exclusion of the quartz (Fig. 57). The rock is very free from minute accessories, a diligent search with a high magnification revealing only a few grains of magnetite and a few needles which appear to be rutile. The carbonate was isolated in methyl iodide and carbon tetrachloride, and has a density superior to 3.00. It dissolves freely in hot hydrochloric acid, and gives a strong reaction for iron, a weak reaction

for magnesium, and none for calcium. It is therefore a magnesia-bearing siderate.

The rock is a banded cherty carbonate rock.

Fig. 57.



No. [6446]. Banded cherty carbonate rock.
x 35 diameters.

[6447]. Near Weelumerina Spring, Hamersley Range, Fortescue River, West Pilbara Goldfield.

M.C.—A brownish rock, with bands of different shades of brown and black, and one of a yellow satiny material in fibres transverse to the bands.

S.—Minerals observed: Iron-ores, quartz.

The base of the section is a fine quartz mosaic, and the bands are due to the accumulation of the iron-ores in certain layers. The bands of clear mosaic measure .3mm., those of the ores generally less. The opaque ores are mainly composed of hematite, united to a sieve-like mass as in [6445], but some octohedra of magnetite are present. The quartz mosaic contains numerous minute rounded plates of a yellow-brown translucent hydrate, while a yellow hair-like hydrate occurs in tufts like leaves of a grass. The satiny band consists of oblique quartz fibres with inclusions of needle-shaped hydrates. It recalls the silicified asbestos ("crocidolite") of South Africa. A portion of the crushed powder gives a noticeable effervescence when dropped into hot acid, revealing the presence of a carbonate. A small section of such a rock cannot be expected to display all the various kinds of bands, and there may be some rich in carbonates as in [6445].

The rock is a banded ferruginous quartzite.

[6449]. Near Weelumerina Spring, Hamersley Range, Fortescue River, West Pilbara Goldfield.

M.C.—A massive light-brown carbonate rock of very finely crystalline texture. The rock effervesces freely with acid.

S.—Minerals observed: Carbonates, iron-hydrates.

The section is formed of an even-grained mosaic of clear carbonates, which are for the most part untwinned. The grains are only slightly interlocked. Here and there large stains of iron-hydrate affect part of the mosaic without disturbing its regularity.

The analysis shows that the carbonate is calcite.

—			Analysis.	Molecular percentage.
SiO_2	..	..	1·69	1·40
Al_2O_3	..	..	0·17	0·08
Fe_2O_3	..	..	0·57	0·17
FeO	..	..	0·88	0·61
MnO	..	..	0·64	0·45
MgO	..	..	0·38	0·47
CaO	..	..	53·23	47·54
Na_2O	..	..	0·35	0·44
K_2O	..	..	*Nil*	..
H_2O +	..	..	0·14	0·38
H_2O –	..	..	0·04	—
CO_2	..	..	42·65	48·46
P_2O_5	..	..	0·02	—
			100·77	100·00

Sp. Gr. 2·73.
Cl [FeS_2], *nil.*
Traces of SO_3 and organic matter.

The rock is a marble.

[**6450**]. Trig. Hill, 144/86, Hamersley Range, Fortscue River, West Pilbara Goldfield.

M.C.—A clastic rock; the fragments are subangular and dull greenish; the matrix is lighter green and dense.

S.—Minerals observed: Actinolite, epidote, zoisite, chlorite, and quartz.

The section shows rock fragments in a finely crystalline matrix, consisting mostly of quartz in a fine mosaic with needles of actinolite, plates of spongy zoisite, and almost opaque aggregates of zoisite grains. The fragments are much altered igneous rocks, in which actinolite and minerals of the epidote group are the chief constituents. One consists almost entirely of interlocked sheaves of radiating actinolite, and is an actinolite rock; most of them contain well-shaped zoisites and epidotes in a chloritic base, with a few needles of actinolite. From the nature and abundance of the secondary minerals in the matrix, it may be inferred that the alteration of the enclosed fragments took place partly after the breccia was formed as such, and that the alteration was assisted by pressure.

The rock is an altered basic igneous breccia.

[**6481**]. Station Peak, West Pilbara Goldfield.

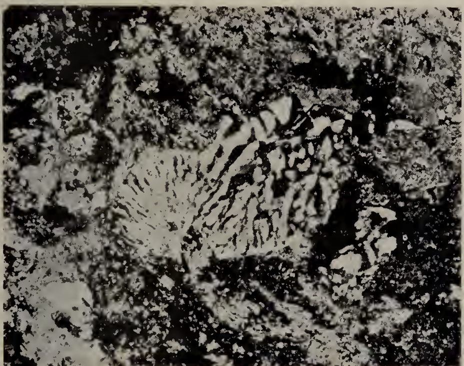
M.C.—A grey-green rock of moderate grain, with a rude foliation which is due to the parallel arrangement of a soft chloritic mineral. The rock effervesces freely with dilute hydrochloric acid.

S.—Minerals observed: Apatite, leucoxene, quartz, muscovite, calcite, and chlorite.

The rock is extremely altered, quartz and apatite being the only original minerals left. But the original structure is not entirely obliterated, and the shapes of the pseudomorphs point to an original ophitic structure of ilmenite and felspar, possibly also of a ferro-magnesian mineral and felspar, and a micropegmatitic structure of quartz and

felspar. The ferro-magnesians are represented by shapeless plates of chlorite, but the nature of the original mineral is not clear. There are two distinct pseudomorphs of felspars, probably pointing to derivation from different species. The first of these consists of fine scales of muscovite, the separate aggregates being embraced by ilmenite. The other pseudomorph is composed of individual crystals of calcite, which exactly replace the felspars. As the felspar was often in micrographic intergrowth of quartz, the result is a graphic structure of quartz and calcite (Fig. 58). Sometimes an original zoning of the felspars is shown

Fig. 58.



No. [6481]. Graphic structure of quartz and calcite. The calcite is in the position of extinction. Crossed nicols. x 42 diameters.

by the muscovite aggregate being lined with a border of calcite and quartz. Graphic structures of quartz and calcite have not been often described, but reference may be made to one in a graphite vein in Ceylon; in this case the structure is ascribed to a simultaneous intergrowth of quartz and calcite during a kind of solfataric action.*

It would be hazardous to assign a name to the original rock, but it is probable that it belonged to the diabase family. It may be described in its present state as a calcite-chlorite-greenstone.

[6482]. Beneath the greenstone on the S.W. side of the range, Station Peak, West Pilbara Goldfield.

M.C.—A green-grey holocrystalline rock of moderate grain.

S.—Minerals observed: Quartz, oligoclase-andesine, orthoclase, muscovite, chlorite, and calcite.

The section shows large rounded to subangular grains of quartz and felspars, and occasionally chloritised biotite set in a cement composed of quartz, chlorite, and calcite. The felspars are cloudy and full of muscovite.

The rock is an arkose.

[6483]. Southern Mass, Station Peak, West Pilbara Goldfield.

M.C.—A massive grey-green rock of moderate grain; the felspars dull and saussuritic.

S.—Minerals observed: Ilmenite, leucoxene, sphene, uralite, felspar, quartz, chlorite, calcite, epidote, and pyrite.

* A. R. Coomara Swamy. On Ceylon Rocks and Graphite. Q.J.G.S., LVI., p. 605, Pl. XXXIII. Fig. 1, 1900.

The rock is altered, the ilmenite being partially replaced by leucoxene, pyroxene entirely altered to uralite, and plagioclase filled with epidote. Ophitic structures are still retained by the leucoxene and uralite, but the uralite plates are ragged, and there has been considerable migration of the uralite into the felspars. The latter are plagioclases with low extinction angles on symmetrically disposed albite lamellae, and they are frequently fringed with wide areas of micropegmatite. In addition to the above minerals, there is some chlorite derived from the uralite, some calcite in the micropegmatite, occasionally granular sphene replacing ilmenite, and a little pyrites.

The rock is a uralitised quartz-dolerite.

[6484]. Northern Mass, Main Ridge, Station Peak, West Pilbara Goldfield.

M.C.—A massive green and white rock of coarse grain, the felspars in part white and lustrous, in part saussuritic.

S.—Minerals observed: Ilmenite, leucoxene, amphiboles, chlorite, felspar, epidote, calcite, quartz, and sillimanite.

The rock is much altered, but appears to have been non-ophitic. There is a little brown hornblende, which is considered original, but most of the amphibole is a pale green, slightly pleochroic, variety which is probably uralite. It is largely altered to chlorite and calcite, and these minerals are also found within the felspars. Considerable areas of the slide are occupied by a coarse micropegmatite, into which idiomorphic felspar pseudomorphs project. The latter are saussuritic, with large granules of epidote, while the felspar of the intergrowths is rusty brown and appears to be orthoclase. There are also large quartz grains in addition to that found in the micropegmatite, and these contain sillimanite needles. The ilmenite formed large skeletal plates embracing the felspars, and is now represented almost entirely by leucoxene.

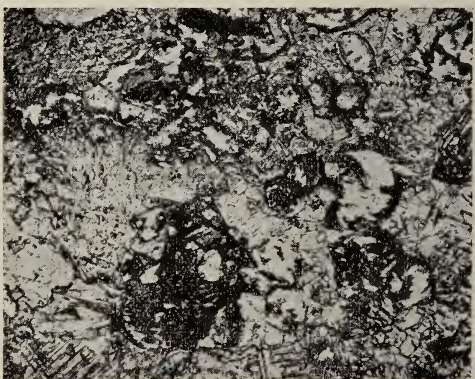
The rock is a uralitised quartz-hornblende-dolerite.

[7546]. ¼-mile N.E. Trig. Station K. 31, Gascoyne River.

M.C.—A coarse-grained greenish carbonate rock with contact minerals.

S.—Minerals observed: Carbonates, chondrodite, chlorite, serpentine, and iron-ores.

Fig. 59.



No. [7546]. Dedolomitised limestone with chondrodite. x 22 diameters.

The carbonate of which the rock is mainly composed appears to be calcite. It forms a coarse-grained mosaic of slightly interlocking. roughly equal grains, often very much twinned. The next mineral in amount is chondrodite, or its pseudomorph in serpentine and dolomite (Fig. 59). The chondrodite occurs in large rounded grains, without definite crystalline form, penetrated by irregular cracks, and showing polysynthetic twin lamellae. It is strongly refringent, and pleochroic with honey-yellow and pale yellow tones. The birefringence is high, the axial angle moderate, and the mineral is optically positive. The distinction from epidote is clear from the absence of well-defined cleavage, the regularity of the birefringence in each individual, and from the greater angles of extinction normal to the twin plane. Moreover, the analysis shows that the mineral in question is mainly a magnesian silicate. Certain pseudomorphs consisting of serpentine, penetrated by strings of a granular carbonate, are taken to be after chondrodite. The carbonate, from its great difference of relief and absorption on rotation, is probably dolomite. There are also chloritic pseudomorphs of a feebly birefringent pennine, which seem to replace a mica. There is one large patch of iron-ore in the section.

—	Analysis.	Molecular percentage.
SiO_2	10·86	8·34
Al_2O_3	0·67	0·31
Fe_2O_3	trace	..
FeO	0·80	0·51
MnO	0·22	0·25
MgO	21·42	24·68
CaO	29·80	24·53
Na_2O	0·32	0·24
K_2O	0·06	0·03
H_2O+	2·43	6·22
H_2O-	0·13	..
P_2O_5	0·11	0·04
CO_2	33·20	34·78
SO_3	0·11	0·07
	100·25	100·00

Sp. Gr.:—2.76.

The analysis shows that the molecular proportions of lime and magnesia are about equal, so that the rock was probably a dolomite, but has suffered the change called by Teall "dedolomitisation."* In this change the magnesia has combined with silica, thus rendering the rock poorer in CO_2, and leaving the carbonate as calcite.

The rock is now a marble with chondrolite and serpentine.

[7547]. South leg of Bangemall Anticline, Bangemall, Gascoyne Goldfield.

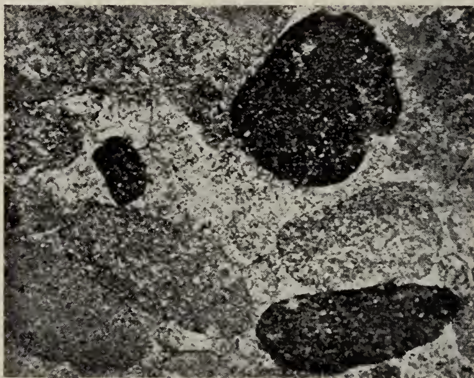
M.C.—A dark-coloured earthy limestone.

S.—Minerals observed: Carbonates, quartz, mica, and iron-hydrates. The structure is peculiar. Rounded and elliptical fragments (up to 1.5 mm. diameter) of fine-grained material are enclosed in a cement of

* J. J. H. Teall. On Dedolomitisation. Geol. Mag. Dec. IV., Vol. X., p. 513, 1903.

coarse-grained carbonates, which often are moulded on the rounded forms (Fig. 60). The constant rotundity of the fragments negatives

Fig. 60.



No. [7547]. Aggregates of dense carbonates in a coarser matrix. x 21 diameters.

the idea that the rock is brecciated, and the structure must therefore correspond to something original. Of the alternatives that the fragments are of organic origin, or that they were oolite grains, the latter seems the more probable. The rounded aggregates are for the most part composed of fine untwinned polygonal carbonate grains, but a few are composed of fine quartz mosaics with occasional rhombohedra of carbonate and flakes of mica. The cement is mostly of carbonate, but includes mica and quartz. The mica is pale yellow, and pleochroic, uniaxial, and negative in sign, and appears to be phlogopite.

—	Analysis.	Molecular percentage.
SiO_2	11·02	9·07
Al_2O_3	0·57	0·28
Fe_2O_3	trace	..
FeO	0·95	0·65
MnO	0·16	0·11
MgO	3·53	4·36
CaO	45·68	40·28
Na_2O	0·32	0·26
K_2O	0·42	0·22
H_2O + ...	0·25	0·69
H_2O —	0·06	..
P_2O_5	0·16	0·05
CO_2	37·24	44·03
	100·62	100·00

Sp. Gr., 2.73.

The rock effervesces freely with weak acid, and the analysis shows that the carbonate must be mainly calcite.

The rock is an impure marble.

[7548]. North leg of Bangemall Anticline, Gascoyne Goldfield.

M.C.—A grey carbonate rock of fine grain, with occasional nests of quartz.

S.—Minerals observed: Carbonates, quartz, iron-hydrates, tourmaline, mica.

The section is formed of a coarse mosaic of interlocking grains of a slightly stained carbonate. The greater part of the quartz is enclosed poecilitically as small irregular grains within the plates of carbonate. Here and there, however, finer groups of quartz take a part in the main mosaic, and these, if of clastic origin, are recrystallised, since small rhombohedra of carbonates are found within them. The carbonates have an uniform appearance and are probably dolomite. There are a few flakes of mica and an occasional prism of tourmaline.

	Analysis.	Molecular percentage.
SiO_2 ...	44·95	39·84
TiO_2 ...	0·21	0·13
Al_2O_3 ...	4·00	2·02
Fe_2O_3 ...	trace	...
FeO ...	2·01	1·44
MnO ...	0·43	0·32
MgO ...	11·31	14·19
CaO ...	14·23	13·09
Na_2O ...	0 24	0·31
K_2O ..	0·10	0·09
H_2O + ...	1·24	3·54
H_2O − ...	0·11	...
P_2O_5 ...	0·18	0·07
CO_2 ...	21·32	24·94
SO_3 ...	0·03	0·02
	100·36	100·00

Sp. Gr. 2·67.

The excess of MgO and CaO over CO_2 is explained by the occurence of mica and tourmaline. The carbonate is dolomite. The silica is higher than inspection of the slide would suggest.

The rock is a siliceous dolomite.

[7549]. North leg of Bangemall Anticline, Gascoyne Goldfield.

M.C.—A fine-grained sugary quartzite, mottled in brown with iron-oxides.

S.—Minerals observed: Quartz, tourmaline, zircon, chlorite, and limonite.

The section shows a fairly even-grained, coarse mosaic of interlocking quartz grains. The original rounded nature of the clastic quartz can be made out by the difference between the inclusions in them and the clearer cementing quartz. There are a few clastic crystals of a strongly refringent pleochroic blue-brown mineral whose optical properties agree with tourmaline, and smaller grains of zircon. Limonite and chlorite fill a few interstices in the mosaic.

The rock is a quartzite.

[7550]. Near the Gem, G.M.L. 1, Bangemall, Gascoyne Goldfield. Field occurrence—Interbedded in the Bangemall anticline.

M.C.—A spotted rock with a poor cleavage; the white spots are sheared out into long lenticles. The matrix is dense black and fine-grained.

S.—Minerals observed: Epidote, calcite, quartz, iron-ores, and chlorite.

The matrix is still very dark in section owing to the predominance of arborescent opaque bodies, probably iron-ores. Between these appear small grains of quartz or untwinned felspar. The spots consist mainly of zoisite and epidote in large granules, and a little quartz. The parts of the spots which have been drawn out by shearing consist of calcite and chlorite.

It is possible that the rock is a sheared porphyritic basic igneous rock, but its original nature is obscure.

[7557]. Ironstone Hill, Bangemall Goldfield.

M.C.—A coarse-grained quartz rock, dense brown owing to the presence of limonite between the quartz grains.

S.—Minerals observed: Quartz and limonite.

The section shows a very coarse quartz mosaic of rounded or polygonal quartz grains. Most of these show stain shadows. Between the individual grains and along their cracks are thick growths of limonite with a fibrous structure perpendicular to the boundaries.

The rock is a quartzite with ferruginous cement.

[7561]. Bangemall, Gascoyne Goldfield.

M.C.—A massive green rock of fine grain, the constituent minerals not recognisable in the hand specimen. The rock effervesces freely with dilute hydrochloric acid.

S.—Minerals observed: Leucoxene, calcite, chlorite, quartz, felspar, and epidote.

The rock is very much altered, and the original structures quite obliterated, except that it seems to have been rock of fine grain. It is now composed of a matrix of quartz or untwinned felspar and chlorite, in which lie large irregular plates of calcite, and small patches of leucoxene; occasionally small prisms or laths of untwinned plagioclase with low extinction angles may be recognised. There is also a little epidote. The analysis shows that the rock belonged to the basalt-diabase family, as is evident by comparison with others given below. The addition of carbon dioxide and water to the rock have probably reduced the percentage of the other constituents.

—	I.	II.	III.	IV.
SiO_2	45·36	47·36	51·22	42·67
TiO_2	1·69	0·51	2·42	1·19
Al_2O_3	13·78	16·79	14·06	7·63
Fe_2O_3	1·74	1·53	4·32	0·61
FeO	11·54	7·93	8·73	9·05
MnO	0·17	0·44	0·16	0·14
MgO	6·23	6·53	4·42	8·79
CaO	8·07	10·08	8·33	8·13
Na_2O	1·71	2·85	2·55	1·56
K_2O	0·33	0·84	1·25	0·19
H_2O + ...	4·47	3·05	1·28	14·01
H_2O —	0·22			—
P_2O_5	0·26	0·26	0·25	0·10
CO_2	4·49	0·48	0·19	5·76
Fe	0·08	1·96	0·49	0·08
2	0·09			0·09
	100·23	100·61	99·67	100·00
Sp. Gr.	2·85	3·081	2·98	

I. [7561].

II. Diabase, Luphodsthal, zwischen Allrode and Treselburg, Harz. Rosenbusch Gesteinlehre, p. 336, 1901.

III. Hunnediabas, Whin Sill. Cauldron Snout, Durham, Rosenbusch, loc. cit., p. 336.

IV. Molecular percentage of [7561].

[7562]. 1½ miles S. of Bangemall, Gascoyne Goldfield. Field relations—An interstratified lava.

M.C.—A dense greenish rock with conchoidal fracture. A red crust, in which small hollows represent small amygdales in the rock.

S.—Minerals observed: Carbonate, quartz, chlorite, and sphene.

A few large irregularly shaped crystals of carbonate lie in a fine-grained mosaic of quartz, chlorite, and a granular mineral of high birefringence which appears to be sphene rather than rutile. Structural relations are quite obliterated. While the silica percentage of the rock would place it in the acid group, the amounts of alumina and alkilies are too low, and that of magnesia is too high; it appears more probable therefore that the rock has suffered partial silicification.

It is a much altered igneous rock.

—	I.	II.	III.	IV.
SiO_2	68·60	69·03	68·36	68·99
TiO_2	1·56	..	..	0·42
Al_2O_3	10·18	15·82	13·24	6·02
Fe_2O_3	1·34	4·18	1·29	0·51
FeO	3·65	..	3·39	3·06
MnO	0·13	trace	0·27	0·11
MgO	4·46	0·85	1·15	6·73
CaO	1·59	0·79	2·51	1·71
Na_2O	0·79	2·95	2·05	0·76
K_2O	2·76	5·66	5·34	1·77
H_2O + ...	2·38	0·89	2·63	7·98
H_2O —	0·24	..	..	..
P_2O_5	0·15	..	..	0·07
CO_2	1·32	..	..	1·81
Fe	0·03	..	..	0·03
S_2	0·03	..	..	0·03
	99·21	100·17	100·23	100·00
Sp. Gr.	2·60	..	2·456	..

I. [7562].
II. Quartz porphyry, Black Forest. Rosenbusch. Gesteinslehre, p. 256, 1901.
III. Hypersthene-andesite, Sweden. Rosenbusch. loc. cit., p. 310.
IV. Molecular percentage of [7562].

[7563]. 1½ miles S. of Bangemall, Gascoyne Goldfield. Field relations:—

M.C.—A dark massive rock of dense grain, with large amydules of earthy brown material, calcite, and siderite.

S.—Minerals observed: Iron-ores, quartz and chlorite, and rutile.

The rock resembles [7562], except for the absence of carbonates, the substitution of rutile for sphene, and a slightly coarser grain.

It is probably also a silicified igneous rock.

[7564]. North leg of Bangemall Anticline, Bangemall, Gascoyne Goldfield.

M.C.—A fissile and banded rock of a bluish-white colour. The bluer bands are aphanitic, the white bands of coarser grain.

S.—Minerals observed: Quartz, muscovite, and limonite.

The section shows the banding seen in the hand specimen, which no doubt is due to the development of foliation. The clearer bands are formed of a fine mosaic of polygonal quartz grains with occasional limonite pseudomorphs after some iron-ore. The light brown bands

consist mainly of very fine muscovite scales with subordinate quartz and numerous large and minute patches of limonite.

—	Analysis.	Molecular percentage.
SiO_2	92·30	94·21
TiO_2	0·22	0·17
Al_2O_3	2·98	1·78
Fe_2O_3	0·89	0·34
FeO	trace	..
MnO	*Nil*	..
MgO	0·62	0·95
CaO	*Nil*	..
Na_2O	0·52	0·51
K_2O	1·06	0·69
H_2O + ...	0·33	1·12
H_2O —	0·12	..
PO	0·04	0·02
CO_2	0·04	0·06
Fe	0·10	0·15
S_2	0·11	..
Organic matter ..	0·28	..
	99·61	100·00
Sp. Gr. ..	2·61	

The mica is in less amount than appears from an examination of the section.

The rock is a micaceous quartz-schist.

[7615]. Secret Creek, Ashburton River, Ashburton Goldfield.

M.C.—A dark carbonate rock of fine grain. There is a limited effervescence with weak acid.

S.—Minerals observed: Carbonates, muscovite, and quartz.

The structure distinctly resembles that of [7547], in that aggregate of very fine untwinned carbonates are cemented by a coarser mosaic of the same mineral, but the aggregates are not always so well rounded, and might in this case have arisen through brecciation. Muscovite is common both in the aggregates and in the cement, and a little quartz occurs in the latter.

—	Analysis.	Molecular percentage.
SiO	3·15	2·43
Al_2O_3	0·06	0·03
FeO	0·90	0·58
MnO	0·14	0·09
MgO	21·65	25·08
CaO	29·59	24·49
Na_2O	0·05	0·04
K O	0·66	0·03
H_2O + ...	0·05	0·13
H_2O —	0·02	..
P_2O_5	trace	..
CO_2	44·72	47·10
SO_3	trace	..
	100·39	100·00

Sp. Gr.

The rock is practically a pure dolomite.

[7616]. Secret Creek, Ashburton River, Ashburton Goldfield.

M.C.—A dark, massive, even-grained rock of coarse texture, showing fresh cleavage surfaces of elongated felspars.

S.—Minerals observed: Ilmenite, plagioclase, orthoclase, pyroxene, hornblende, biotite, quartz, epidote, zoisite, and chlorite.

The pyroxene is ophitic with respect to the plagioclase, while the orthoclase forms a micro-pegmatitic intergrowth with quartz. Symmetrical extinction angles amounting to 27 degrees were observed on albite twins of plagioclase, showing this mineral to be labradorite; it is not probable, however, that all the plagioclase is so basic. It occurs in elongated prisms, and is for the most part in good preservation, but a few crystals include pale minerals of the epidote group. The pyroxene has a slight lilac tint, and is not pleochroic; it has an extinction angle of 45 degrees and a moderate axial angle. Twinning on the ortho-pinacoid is occasionally seen, and owing to incipient decomposition along planes parallel to the base (001), this gives rise to a "herring-bone" structure (Fig. 61). This decomposition is usually

Fig. 61.

No. [7616]. Quartz-dolerite. In the centre is a twin of augite showing incipient herring-bone structure. x 21 diameters.

seen on the exterior of the crystal, but occasionally affects irregular areas in the interior, giving rise to a pale-green feebly birefringent substance. It preserves an uniform optical orientation within each crystal of pyroxene, but extinguishes in a different position from the host. Its exact nature remains undetermined. The hornblende is of a brown-green pleochoric variety, which forms outgrowths on the pyroxene, with extremely irregular boundaries between the two minerals. This suggests that it has been derived magmatically from the augite, as explained in the introduction. The biotite bears a similar relation to the pyroxene, but can sometimes be seen to be moulded on the hornblende, and thus to be posterior to it. But occasionally these two minerals are associated in parallel position. The micro-pegmatite occupies a position interstitial to the other minerals, but it is found most often in the neighbourhood of the plagioclase. In one case it appears to have invaded the plagioclase. The

constituent minerals can thus be arranged in two groups according to their order of consolidation:—

(*a.*) Ilmenite, labradorite, pyroxene.
(*b.*) Hornblende, biotite, orthoclase, and quartz.

—	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2 ..	51·93	49·42	51·22	50·71	50·55	49·67	54·29	57·76
TiO_2 ..	1·75	1·95	2·42	1·92	1·58	1·13	1·37	1·54
Al_2O_3 ..	14·26	14·95	14·06	14·78	15·00	12·46	8·77	9·21
Fe_2O_3 ..	2·49	1·38	4·32	3·52	2·54	1·77	0·98	0·54
FeO ..	10·76	10·76	8·73	8·95	7·90	8·71	9·37	9·39
MnO ..	0·57	0·47	0·16	0·31	..	0·09	0·50	0·41
MgO ..	5·28	6·16	4·42	5·90	6·25	10·50	8·28	9·68
CaO ..	7·89	9·85	8·33	8·21	7·85	9·57	8·84	11·06
Na_2O ..	2·79	2·70	2·55	2·76	3·53	2·42	2·82	2·73
K_2O ..	0·81	0·72	1·25	1·39	1·10	0·63	0·54	0·48
H_2O +	1·13	0·77	1·28	1·78	3·14	2·82	3·94	2·69
H_2O —	0·09	0·09			0·55	0·37	..	..
P_2O_5 ..	0·31	0·55	0·25	..	..	0·13	0·13	0·24
CO_2 ..	*Nil*	*Nil*	0·19	0·25	..	trace	..	..
Fe ..	0·07	0·12	0·49	..	..	..	0·08	0·13
S_2 ..	0·08	0·14					0·08	0·14
	100·21	100·03	99·67	100·48	99·99	100·27	100·00	100·00
Sp. Gr...	3·00	3·01	2·98	2·944	2·92	2·96	..	..

I. [7616].
II. [7728].
III. Whin Sill, Cauldron Snout, Durham. Teall. Q.J.G.S. XL., p. 654, 1884.
IV. Whin Sill Crags near Roman Station of Bourgevicus. Teall, loc. cit.
V. Carn Llidi, St. David's Head, Elsden. Q.J.G.S., LXIV., p. 280, 1908.
VI. Carn Hen. St. David's Head. Elsden, loc. cit., p. 278.
VII. Molecular percentage of [7616]
VIII. Molecular percentage of [7728].

Analyses of rocks of this class will naturally show a greater variation than is usual in well defined rock families, owing to the extreme chemical differences between the earlier and later products of consolidation, which may be combined in various proportions. With the exception of the state of oxidation of the iron, [7617] is very similar to III. The latter rock, however, contains enstatite. It is obvious that in [7616] the pyroxene cannot be near the diopside molecule, since the ferrous iron and magnesia molecules are in great excess over those of lime, most of which besides must go to the plagioclase. That the pyroxene does not belong to Wahl's group of enstatite-augites, however, is shown by its axial angle, which, though smaller than that of a common augite, is nevertheless fairly large.

The rock is a quartz-gabbro or dolerite.

[7617]. Trig. Station C. 8, near Dead Finish, Ashburton River, Ashburton Goldfield.

M.C.—A brown massive carbonate rock of dense texture. A red-brown crust. There is slight effervescence with dilute acid.

S.—Minerals observed: Carbonates, quartz, muscovite, apatite, magnetite, and iron-hydrates.

The rock is composed mainly of carbonates, but the slide is stained brown with iron-hydrates, and shows numerous clastic grains of quartz, muscovite, and less commonly magnetite and apatite. The slight effer-

vescence, combined with the proportions of lime and magnesia in the analysis, show that both calcite and dolomite must be present. It is difficult to distinguish them in section, for the iron-staining obscures the boundaries of the grains, but the rock is brecciated and recemented by veins of a carbonate in the form of prisms which are perpendicular to the wall of the veins. It is probable that the fragments of the breccia are dolomitic, and that the cementing carbonate is calcite.

—	Analysis.	Molecular percentage.
SiO_2	15·78	13·65
TiO_2	*Nil*	...
Al_2O_3	2·50	1·25
Fe_2O_3	2·11	0·68
FeO	6·18	4·42
MnO	1·52	1·10
MgO	12·09	15·58
CaO	22·84	21·04
Na_2O	0·35	0·29
K_2O	0·47	0·26
H_2O + ...	0·17	0·49
H_2O −	0·19	...
P_2O_5	0·53	0·19
CO_2	35·02	41·04
SO_3	*Nil*	...
	99·75	100·00
Sp. Gr.	2·89	...

The rock is an impure siliceous dolomite.

[**7618**]. Gorge Creek, near Reserve M.5, Ashburton Goldfield. Field occurrence—A dyke.

M.C.—A massive light-coloured rock of fine grain, not markedly porphyritic.

S.—Minerals observed: Apatite, zircon, muscovite, quartz, chlorite, and iron-ores.

The accessories, quartz and chlorite, lie in a crypto-crystalline sericitic groundmass, with a development of larger muscovite in subparallel lines.

—	I.	II.	III.
SiO_2	76·80	75·7	79.02
TiO_2	0·14	trace	0·11
Al_2O_3	13·91	13·5	8·42
Fe_2O_3	*Nil*	0·5	...
FeO	1·00	1·7	0·86
MnO	0·26	trace	0·23
MgO	0·77	0·2	1·19
CaO	0·24	0·7	0·27
Na_2O	1·16	2·4	1·15
K_2O	3·04	5·3	1·99
H_2O + ...	1·88	...	6·44
H_2O −	0·07	...	...
P_2O_5	0·33	trace	0·11
CO_2	0·08	...	0·14
Fe	0·03	...	0·03
S_2	0·03	...	0·04
	99·75	100·9	100·00
Sp. Gr.	2·73	2·64	

I. [**7618**].
II. Porphyroid, Thuringia, Rosenbusch, Gesteinslehre, p. 457, 1901.
III. Molecular percentage of [**7618**].

The rock is a sheared acid igneous rock and is now a porphyroid.

[7724]. The Gorge, Irregully Creek. Ashburton Goldfield.

M.C.—A red-coloured carbonate rock of fine grain, with patches and strings of a colourless carbonate. No effervescence, with dilute acid.

S.—Minerals observed: Carbonates and iron-hydrates.

The section shows that the red part of the rock consists of fine untwinned carbonates, often stained with reddish iron-hydrates, while the white veins consist of a coarse-grained colourless carbonate. The lack of effervescence, and the equal proportions of lime and magnesia in the analysis render it probable that all the carbonate is dolomite. The analysis further reveals that a small proportion of silica or silicates has escaped detection in the section.

	Analysis.	Molecular percentage.
SiO_2	3·14	2·44
TiO_2	*Nil*	...
Al_2O_3	0·02	0·01
Fe_2O_3	0·33	0·09
FeO	0·39	0·25
MnO	0·68	0·45
MgO	20·70	24·14
CaO	29·53	24·61
Na_2O	0·05	0·04
K_2O	0·12	0·06
H_2O + ...	0·08	0·21
H_2O −	0·14	...
CO_2	44·89	47·58
P_2O_5	0·11	0·04
SO_3	0·13	0·08
	100·32	100·00
Sp. Gr.	2·85	

The rock is a dolomite.

[7725]. The Gorge, Irregully Creek, Ashburton Goldfield.

M.C.—A light-coloured carbonate rock of almost flinty texture, with occasional strings of transparent carbonate.

S.—Minerals observed: Carbonates, quartz, and iron-oxides.

The rock consists almost entirely of very fine untwinned carbonate grains, with occasional nests in which larger crystals occur. There are occasional patches of quartz mosaic or of iron-hydrates. The banding is due to a slight variation of grain. The analysis shows that the carbonate is all dolomite.

—	Analysis.	Molecular percentage.
SiO_2	8·27	6·49
TiO_2	0·13	0·07
Al_2O_3	0·52	0·24
Fe_2O_3	*Nil*	...
FeO	0·35	0·23
MnO	0·46	0·31
MgO	19·49	22·96
CaO	27·57	23·19
Na_2O	trace	...
K_2O	0·12	0·06
H_2O + ...	0·06	0·18
H_2O −	0·03	...
P_2O_5	trace	...
CO_2	43·17	46·25
SO_3	0·05	0·02
	100·22	100·00
Sp. Gr.	2·85	

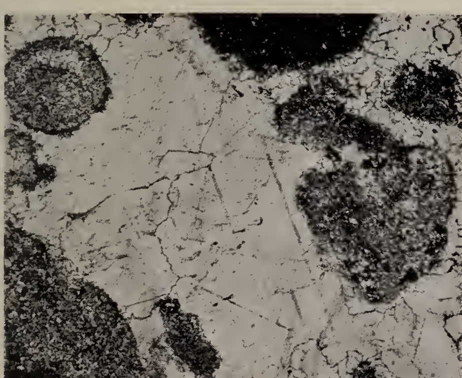
The rock is a siliceous dolomite.

[7726]. The Gorge, Irregully Creek, Ashburton Goldfield.

M.C.—A white brecciated carbonate rock with a cement of coarsely crystalline carbonate. There is no effervescence with dilute acid.

S.—Minerals observed: Carbonates, tremolite, mica, chlorite, and iron-ores.

Fig. 62.



No. [7726]. Aggregates of fine grained carbonates, cemented by large grains of calcite. x 21 diameters.

The structure is very similar to that of [7547], in that dense rounded aggregates of very fine-grained untwinned carbonates are cemented by large plates of a twinned carbonate (Fig. 62). A small amount of silicate occurs both among the fine and the coarse carbonates, and is principally tremolite. There is also a colourless mica and a little chlorite, and a few specks of iron-oxides. The proportions of lime and magnesia show that the carbonate is mostly dolomite, making allowance for a slightly greater proportion of magnesia than lime in the silicates.

—	Analysis.	Molecular percentage.
SiO_2	1·96	1·51
Al_2O_3	0·60	0·27
Fe_2O_3 ...	0·55	0·16
FeO	0·11	0·07
MnO	0·39	0·26
MgO	22·13	25·66
CaO	29·42	24·35
Na_2O	0·09	0·07
K_2O	0·04	0·02
H_2O + ...	*Nil*	—
H_2O −	0·11	—
P_2O_5	trace	—
SO_3	trace	—
CO_2	45·18	47·63
	100·58	100·00
Sp. Gr. ...	2·89	

The rock is an impure dolomite.

[7727]. The Gorge, Irregully Creek, Ashburton Goldfield. Field occurrence—Siliceous band in limestone.

M.C.—A red banded siliceous rock almost flinty in texture and with conchoidal fracture. There is no effervescence with dilute acid.

S.—Minerals observed: Carbonate, quartz, and fibrous forms of silica, iron-ores, and muscovite.

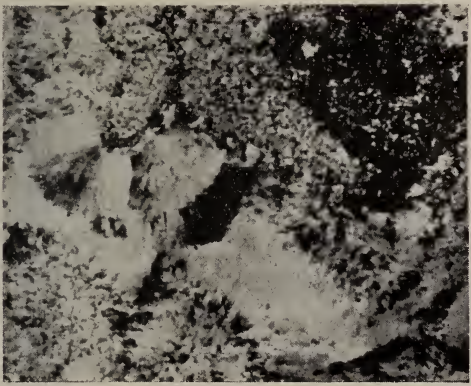
The rock presents a peculiar structure, being composed of rounded or elliptical patches in which carbonates predominate, cemented and veined by clear siliceous material with few carbonates. It thus presents considerable similarity to [7547], and may be regarded as a silicified oolite. The presumed oolitic grains are composed of minute independent rhombohedra lying in a crypto-crystalline quartz base, and are lined by a row of larger idiomorphic carbonates. Often they are fringed within their margin by a radial growth of the fibrous silica, and they are then coarser in texture in the centre.

The siliceous veins are lined on their walls by hemispherical spherulites (Sphärokrystalle) of fibrous varieties of silica, often arranged in two concentric layers; the inner is of finer fibres, of varying birefringence, and negative in elongation; it therefore corresponds with chalcedonite.* The outer fibres are of greater width, are uniform in birefringence, and have positive elongation, and are therefore identical

* *See* M. Lévy and Munier-Chalmas., Mémoire sur diverses formes affectées par le réseau élémentaire du quartz. Bull., Soc., Min., Fr., XV., p. 159, 1892. and Lacroix., Mineralogié de France, tome III., p. 120, 1901. As " calcédoine " represents the English " Chalcedony " we may translate " calcédonite " by " chalcedonite."

with quartzine (Fig. 63). In a few of the spherulites, there is a further repetition of concentric rings of chalcedonite and quartzine. Finally, some of the veins have their interior filled with fairly coarse individuals of quartz, which can be definitely identified by its unaxial character. Sometimes the quartz layer is missing. In the absence of a chemical analysis and of special separation of the carbonate, its nature remains uncertain, but it is probably dolomite. The small amount of iron-ores

Fig. 63.



No. [7727]. Siliceous spherulites in cherty carbonate. Photographed under crossed nicols with the interposition of a gypsum plate. The double nature of the spherulites may be seen from the fact that the white sectors of the inner chalcedonite pass out into black in the quartzine, and *vice versa*. x 42 diameters.

occurs partly as spongy opaque masses of hydrate, and partly as hexagonal plates of translucent red hematite. They cannot be definitely connected with the carbonate.

The rock is a cherty carbonate rock.

[7728]. Irregully Creek, Ashburton Goldfield.

M.C.—A massive dark igneous rock of coarse even grain.

S.—Minerals observed: Apatite, ilmenite, pyroxene, hornblende, plagioclase, orthoclase, biotite, quartz, leucoxene, and chlorite.

The rock presents such a general similarity in composition and structure to [7616] that a detailed description is hardly called for. The nature, decomposition, and structures of the minerals are quite the same. The chief differences lie in the presence of numerous fine apatite needles, and the preponderance of biotite over hornblende. The rock is slightly more altered; leucoxene replaces some of the ilmenite, chlorite is always associated with the biotite, and neither the felspars nor the pyroxene are so clear. The analysis given under [7616] shows how rocks, in almost all respects similar, may yet show considerable variations in chemical composition due to the different proportions of the constituent minerals.

The rock is a quartz-gabbro or dolerite.

[7730]. Coorara Claypan, Ashburton River, Ashburton Goldfield.

M.C.—A brownish finely crystalline carbonate rock. No effervescence with dilute acid.

S.—Minerals observed: Carbonates, quartz, iron-hydrates.

The section is made up of an uneven-grained mosaic of partly interlocking carbonate grains showing few twin lamellae. There are, in addition, a few small areas of fine quartz mosaic with inclusions of carbonates, and spongy masses of iron-hydrates. The analysis shows the carbonates to be dolomite.

	Analysis.	Molecular percentage.
SiO_2	0·23	0·18
TiO_2	*nil*	—
Al_2O_3	0·20	0·09
Fe_2O_3	trace	—
FeO	0·15	0·09
MnO	0·30	0·19
MgO	21·35	24·58
CaO	30·43	24·79
Na_2O	*nil*	—
K_2O	*nil*	—
H_2O + ...	0·06	0·16
H_2O −	0·04	—
P_2O_5	0·10	0·03
CO_2	44·74	49·89
	100·20	100·00
Sp. Gr.	2·87	

The rock is a very pure dolomite.

[7731]. Uaroo, Ashburton Goldfield.

M.C.—A sugary white quartz grit with occasional larger fragments of quartzite or schist, with a poorly developed parallel structure due to shearing.

S.—Minerals observed: Quartz, muscovite, and limonite.

The rock consists of an uneven mosaic of quartz grains, often separated by much opaque matter. Here and there bent flakes of muscovite appear. All the quartz shows strain shadows.

The rock is a quartzite or fine quartz-conglomerate.

[7732]. Country Rock of Dark Horse Reef 37 (P.A. 13), Uaroo, Ashburton Goldfield.

M.C.—A silvery white silky phyllite, very soft to the touch.

S.—Minerals observed: Quartz, muscovite, hematite, rutile, cyanite.

The section shows a very fine-grained matrix of quartz grains, polygonal in outline, in which lie small parallel flakes of muscovite and elliptical plates of micaceous hematite with their long axes parallel to the foliation (Fig. 64). In reflected light the hematite gives white metallic gleams, while with high magnification and transmitted light many of the smaller crystals are seen to be translucent and of a brown-red colour. The thicker plates show the red colour at the edges. With

high powers, the rock is seen to be rich in rutile, occurring sometimes in needles which take their origin within the hematite and project in

Fig. 64.

No. [7732]. Hematite phyllite. x 54 diameters.

all directions into the quartz mosaic, sometimes in isolated and often twinned heart-shaped crystals. A few minute ill-formed crystals supposed to be cyanite are also seen.

	Analysis.	Molecular percentage.
SiO_2	58·84	63·85
TiO_2	1·48	1·20
Al_2O_3	21·59	13·78
Fe_2O_3	4·76	1·93
FeO	0·60	0·54
MnO	0·26	0·24
MgO	2·31	3·75
CaO	0 29	0·34
Na_2O	1·34	1·41
K_2O	5·34	3·69
H_2O+	2·52	9·11
H_2O-	0·04	—
P_2O_5	0·36	0·16
CO_2	*nil*	—
SO_3	*nil*	—
Fe	*nil*	—
S_2	*nil*	—
	99·85	100·00
Sp. Gr.	2·81	

If all the ferric iron be considered as hematite, and the titania as rutile, the mica must be of a variety between phlogopite and muscovite.

A rough calculation of the mineral composition gave the following result:—

		I.	II.
Rutile		1·20	1·48
Hematite... ...		1·93	4·76
Apatite		0·45	0·53
Phlogopite	Mica	11·34	
		...	61·39
Muscovite		48·09	
Quartz		35·77	30·62
Cyanite		1·00	1·22
		100·00	100·00

I. Proportions by molecules.
II. Proportions by weight.

The cyanite is obviously too high. A very slightly higher estimation of the alkalis would reduce it and add to the mica.

The rock is a hematite-phyllite.

[7733]. Country Rock of lode. Ashburton Goldfield.

M.C.—A purple phyllite with a rough cleavage surface, due to the presence of garnets.

S.—Minerals observed: Quartz, muscovite, hematite, rutile, garnet, and cyanite.

The rock bears considerable resemblance to the last, [7732], and differs chiefly in the inverted proportions of the rutile and hematite. The former is here more abundant, and occurs in larger crystals, showing knee-shaped as well as heart-shaped twins. There are a few idiomorphic dodecahedra of a colourless garnet, full of inclusions of rutile. Pseudomorphs of some other mineral appear to be represented by occasional ill-defined spots, which consist of quartz and mica in larger individuals than elsewhere, and lying across the general orientation of the other minerals of the rock.

The rock is a garnet-phyllite.

[7738]. Uaroo, Ashburton Goldfield.

M.C.—A conglomerate of quartz pebbles in a matrix which resembles a phyllite.

S.—Minerals observed: Quartz, iron-ores, and muscovite.

The larger quartz grains lie augen-like in a fine-grained mosaic of muscovite, iron-ores, and quartz. The finer iron-ores are hematite, and are often so abundant as to cause the matrix to become opaque; the larger ores are limonite, apparently after idiomorphic magnetite.

The rock is a sheared impure quartz-conglomerate.

[7741]. Uaroo, Ashburton Goldfield.

M.C.—A greenish quartzite of fine grain.

S.—Minerals observed: Quartz, muscovite, chlorite, magnetite, and pyrites.

The rock is formed of a somewhat uneven-grained mosaic of quartz, the individuals having polygonal outlines and being little interlocked.

There is a considerable amount of chlorite in the interstices of the mosaic, and occasional flakes of muscovite. Zircon forms a rare constituent, but large idiomorphic crystals of magnetite are abundant.

The rock is a quartzite.

[7748]. Weston's. Ashburton Goldfield.

M.C.—A light-coloured grit of angular fragments of quartz, felspar, and flakes of muscovite.

S.—Minerals observed: Quartz, orthoclase, microcline, muscovite, tourmaline, and calcite.

Rounded crystals of quartz and felspars and flakes of muscovite lie in an abundant matrix of calcite. A blue tourmaline occurs rarely. All the constituents show signs of pressure; the quartz, felspars, and calcite are sometimes crushed to a fine mosaic, more often they only give strain shadows. The muscovite plates are bent.

The rock is a crushed calcareous arkose.

[7749]. Weston's, Ashburton Goldfield.

M.C.—A greenish rock with a rude parallel structure, composed of angular quartz grains set in a schistose micaceous matrix.

S.—Minerals observed: Quartz, chlorite, magnetite, limonite, muscovite, tourmaline, and zircon.

Large grains of quartz and magnetite lie in a fine-grained mosaic of quartz, chlorite, muscovite, and limonite, with occasional crystals of zircon and blue tourmaline. The effects of pressure are seen in the strain shadows in the quartz, the cataclastic structure of the iron-ores, and the subparallel arrangements of the muscovite flakes.

The rock is a sheared impure quartzite.

[7750]. Weston's, Country Rock of the Copper Lode, Ashburton Goldfield.

M.C.—A well-cleaved silvery phyllite.

S.—Minerals observed: Quartz, chlorite, muscovite, tourmaline, magnetite, hematite, and rutile.

Abundant thin parallel flakes of muscovite, and broader ragged flakes of chlorite, lie in a fine matrix of quartz. Hematite is abundant in elliptical plates with their long axes parallel to the foliation, and shows bright metallic reflections in side illumination. There is a development of rutile similar to that of [7732] in crystals which are perfectly idiomorphic, with many faces in the prism zone. Magnetite occurs in less amount in larger shapeless plates. Small prisms of tourmaline cross the foliation in all directions.

The rock is a tourmaline-phyllite.

[7756]. Mt. Stuart, Duck Creek, Ashburton Goldfield.

M.C.—A heavy dark banded ferruginous rock, the bands alternately black and metallic, and rusty brown.

S.—Minerals observed: Iron-ores and quartz.

The rock is ferruginous, and the section almost opaque. It shows innumerable small iron-oxide grains in a finely crystalline base of quartz. The ores are arranged in bands of varying denseness. There are a few idiomorphic grains of opaque magnetite, but the majority of the ores are translucent and blood-red in colour, and are to be referred to hematite. There are also translucent brown minerals, sometimes in shapeless lumps, sometimes in rhombohedral shapes, and these appear to be limonite, perhaps pseudomorphosing siderite. The quartz mosaic

includes a few colourless minerals of high relief and low birefringence. They have no characteristic shapes, and are too small for determination.

	I.	II.	III.	IV.	V.	VI.
SiO_2 ...	40·21	63·60	53·36	89·26	40·90	51·56
TiO_2 ...	*nil*	—	—	—	—	—
Al_2O_3 ...	1·80	1·67	5·96	0·92	4·00	trace
Fe_2O_3 ...	54·75	26·78	37·74	8·48	50·08	47·78
FeO ...	*nil*	...	0·09	0·18	0·09	0·90
MnO ...	0·14	0·19				
MgO ...	0·33	0·78	free	free	free	free
CaO	0·23	0·39	free	free	free	free
Na_2O ...	0·52	0·79				
K_2O ...	0·39	0·39				
H_2O + ...	0·97	5·11				
H_2O − ...	0·05	—				
P_2O_5 ...	0·24	0·16				
Fe ...	0·04	0·07				
S_2 ...	0·05	0·07				
	99·72	100·00	96·85	98·84	95·07	99·94

Sp. Gr., 3.58.

I. [7756.]
II. Molecular percentage of same.
*III. VI., Hospital Hill shales. III., Fair average sample, every 3 feet for 225 feet.
IV. Most acid result possible.
V. Most basic result possible.
VI. Average section of typical banded and crumpled series.

The analysis shows that hematite, and next to it hydrates, are the chief iron-ores present. From the presence of magnetite in the rock, one would expect to find a small percentage of FeO. The analyses of similar rocks from South Africa is given for comparison. There is a very close agreement with No. 5.

The rock is a banded hematite-quartzite.

[7757]. Western Slope of Mt. Stuart, Duck Creek, Ashburton Goldfield.

M.C.—A greenish rock with a lenticular (subparallel structure) showing augen of quartz in a micaceous matrix.

S.—Minerals observed: Quartz, chlorite, and muscovite.

There are a few large quartz grains showing strain shadows, and reduced to a fine cataclastic aggregate along certain zones. The bulk of the rock is composed of interlocking small quartz grains with much muscovite and a little chlorite.

The rock is a sheared impure quartzite.

[7896]. Red Hill Copper Mine, two miles east of S. R. Well 45, Ashburton Goldfield.

M.C.—A bluish finely crystalline and banded carbonate rock, veined by a fibrous white carbonate whose crystals are elongated at right angles to the walls of the veins.

* H. F. Marriot. Notes on the Chemical Composition of the Hospital Hill shales. Trans. Geol. Soc., South Africa, VII., p. 27, 1904. The author justly observes that the rocks are ferruginous quartzose sandstones, with little title to the term shale.

The blue parts give no reaction with dilute acid, but the veins exhibit a slight effervescence.

S.—Minerals observed: Carbonates and quartz.

The existence of two distinct species of carbonate in the rock can be easily seen by the difference of relief and of absorption on rotating the section. That of the veins as, no doubt, calcite, but that of the rock appears from the brown tones it shows to be a ferruginous dolomite. The dolomite has been considerably invaded by quartz; the larger plates are in places broken up into a multitude of small idiomorphic rhombohedra still living in parallel position to one another. In the well banded parts of the rock the outlines of the larger plates are lost, and the bands are formed by the collection of the small rhombohedra in parallel rows in a quartz mosaic (Fig. 65). A small quartz vein crosses the rock. The calcite of the veins occurs in elongated crystals, and contains numerous crystals of the dolomite.

Fig. 65.

No. [7896]. Carbonate rock showing incipient banding. x 21 diameters.

The rock is a veined siliceous dolomite, approaching in places a banded cherty carbonate rock.

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INDEX, ETC.—*continued.*

INDEX, ETC.—*continued.*

INDEX, ETC.—*continued.*

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